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STRUCTURE AND OIL AND GAS RESOURCES OF THE OSAGE RESERVATION, OKLAHOMA

BY

DAVID WHITE AND OTHERS

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[The letters in parentheses prefixed to the headings are those used to designate the chapters for advance publication.]

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STRUCTURE AND OIL AND GAS RESOURCES OF THE OSAGE RESERVATION, OKLAHOMA.

INTRODUCTION.

By DAVID WHITE.

Purpose of this report.—Responding to the imperative need for increasing to the utmost the petroleum supply of the United States, the Geological Survey, since we entered the war, has largely concentrated its investigations of oil fields in the most promising undeveloped territory, such as Wyoming and the midcontinent-Texas region, and especially in the Osage Reservation in Oklahoma.

The Osage Reservation demands particular attention at this time because (1) it contains a great acreage of unleased oil lands; (2) the productivity of the developed areas is high and well sustained; (3) anticlines and domes are numerous in the greater part of the area, and the development and tests indicate that most of the structurally favorable folds will yield oil; (4) the oil is of paraffin grade, mainly 35° to 36° Baumé, yielding about 23 per cent of gasoline in present practice but capable of producing over 50 per cent by the best methods; (5) pipe lines and refineries are already at hand; and (6) the Office of Indian Affairs, which administers the lands, held in common by the Osage Indians, is offering leases of hundreds of quarter sections to openly competitive bidders on advertised dates.

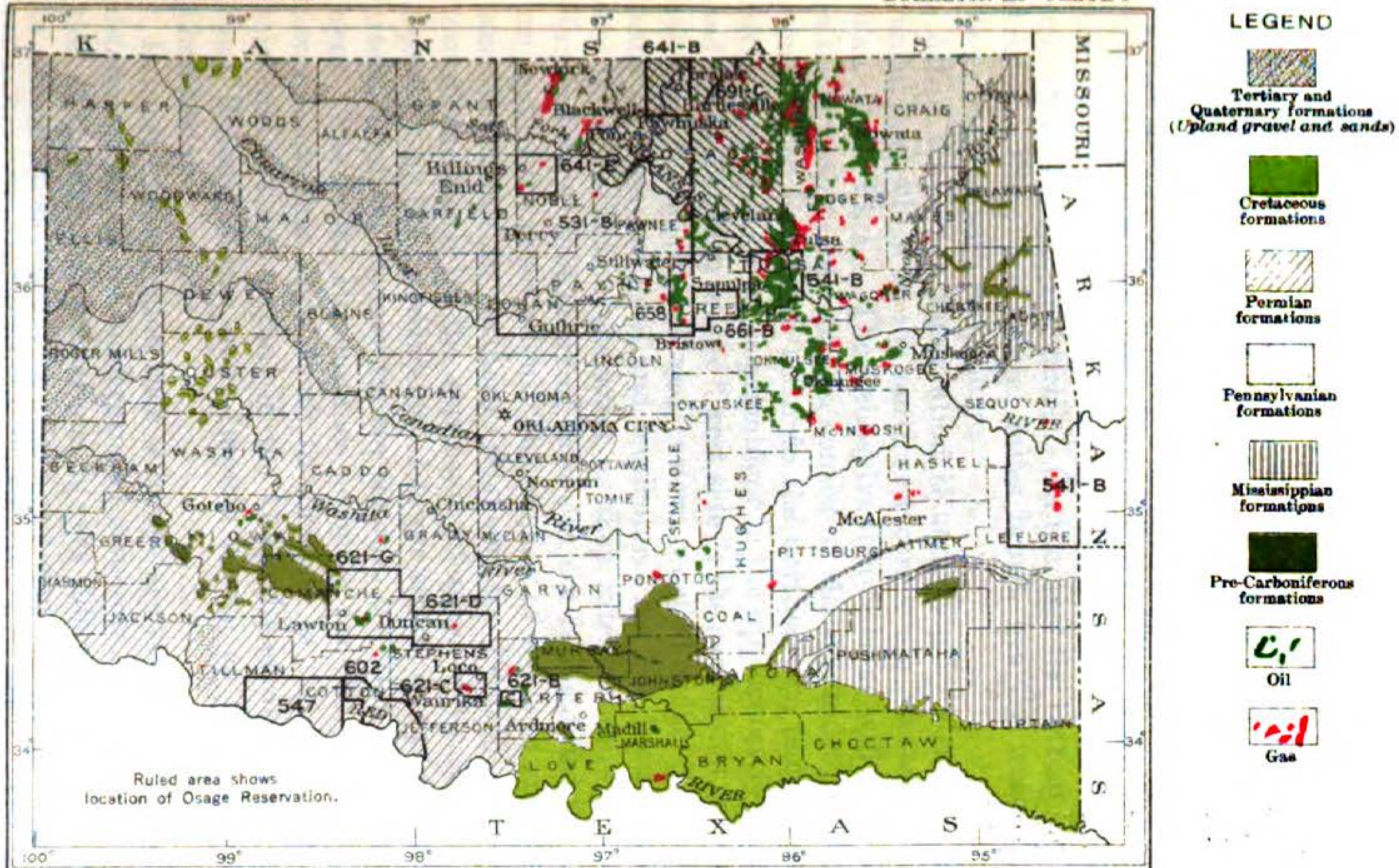
Between May 30, 1917, and May 19, 1918, four auctions of leases were held, offering 9,280 acres May 31, 1917, 20,000 acres November 12, 1917, 32,160 acres February 14, 1918, and 51,360 acres May 18, 1918. About 1,160,000 acres remain (August, 1918) to be leased.

A review of the bonuses paid shows a most regrettable lack of information as to the relative values of the tracts on the part of some of the bidders and suggests that many of them had little if any geologic guidance. Although some of the oil operators had examinations made by geologists for their exclusive benefit, many tracts in which the structure is favorable to the occurrence of oil were neglected or wholly disregarded, and large bonuses were paid for other tracts that will probably never yield oil in commercial quantities. These facts are all the more unfortunate because the leases made at the last three sales require drilling within nine months after the date of approval of the lease. Dry holes will be drilled, even when located in accordance with the best geologic information obtainable, but they will be fewer, especially in regions like this, where the oil and gas, if present, are as a rule found in anticlines and domes. The loss of the driller in bonuses, labor, equipment, supplies, and transportation and even his loss of time and opportunity through fruitless boring in an area of distinctly unfavorable structure constitute an economic waste that affects the military efficiency of the Nation.

This report is therefore issued to supply an evident need for geologic information regarding the Osage lands. In the separate papers the most practical and immediately available conclusions reached by the geologists as to the structure and oil prospects in the townships already examined are published for the immediate use of the oil man. In preparing these papers the geologists have departed somewhat from the more formal and comprehensive style characteristic of the reports of the Survey, in order to put the data into the hands of the public at the earliest possible moment. Important studies, such as those of water relations or of the continuity and porosity of the sands—features that strongly affect and may even nearly neutralize the influence of the geologic structure in controlling the distribution of oil and gas—require considerable time and are therefore necessarily postponed for incorporation in the more detailed reports to follow.

Field examinations.—The field investigations in the Osage Reservation were conducted with the cooperation of the Office of Indian Affairs and of the commissioner for the Osage Indians. The examinations, which have been carried on for over a year by K. C. Heald, who has had immediate charge of the work, and by the geologists who were associated with him, were interrupted in order that the office work of preparing the township maps and descriptions might be completed, but some of the geologists are now (July, 1918) still in the field. The field work, which included plane-table mapping with telescopic alidade under many hardships in addition to those of the severe winter, was carried forward with splendid teamwork and with gallant and indefatigable emulation. In recording his admiration for the esprit and high standard of this war work, done by geologists in professional civil service, the writer believes he expresses the appreciation not only of the Geological Survey but of the oil operators as well.

General features of the region.—The geographic position of the Osage Reservation, which forms Osage County in northeastern Oklahoma, is shown in Plate I, which also shows the distribution of the principal known oil and gas fields in the State. The reservation, or



GEOLOGIC MAP OF OKLAHOMA SHOWING OIL AND GAS FIELDS
Heavy numbers refer to numbered bulletins in which other oil fields in Oklahoma are described

50 0 50 Miles

1918

"Nation," as it is commonly called in the region, lies in the heart of the Mid-Continent oil field. It has fair railway facilities, but its wagon roads lack much in number and quality. Three pipe lines extend to Mississippi River and eastern refineries; four carry Osage oil to Gulf ports.

Wooded ridges, mostly capped by sandstones, characterize the "east side"—that part of the reservation east of R. 7 E.—especially in the southeastern portion. Much of the "west side," very little of which is yet leased for oil, is open rolling prairie, now cattle range, with a rather deeply incised dendritic drainage system cutting bluff-forming limestones. The valleys of the larger creeks are broad, covered with alluvium, and fertile. On the west the bottom lands along Arkansas River are several miles broad, heavily wooded, and in places covered with sand dunes.

All of the Osage Reservation is underlain by strata of Pennsylvanian age, which in the northwest corner are covered by the Permian. (See Pl. I.) The Pennsylvanian beds, as will be fully noted in the township descriptions, consist of shales, sandstones, and limestones. The limestones occur in the northeastern part of the reservation, but they are most prominent in the uppermost Pennsylvanian and in the Permian on the "west side"; the sandstones are more conspicuous in the central and eastern wooded ridge country, where many of them are local and lenticular. All the limestones tend to lose their distinctive character as they extend southward from the Kansas line, so that many of them can not be identified in the southern part of the reservation. The number of red beds increases in the same direction. In northern Oklahoma the Pennsylvanian thickens toward the south by the expansion of some of its formations and especially by the introduction of lower strata, due to the northward extension of the Pennsylvanian sea into the Mid-Continent embayment. The latter circumstance accounts for the presence of many lower sands that are difficult to correlate in the drill logs, but the thickening is not marked in the Osage Reservation, where all the basal Pennsylvanian sands (mostly known as Bartlesville) are of Cherokee age.

In most of the region rock outcrops are reasonably good, but the determination of the underground structure, through the examination of the exposed formations, is very difficult and even impossible in certain areas, especially in the east-central and southern parts of the region, on account of the disappearance of some of the limestones, the irregularity in the sandstones, and the concealment of many of the intervening strata by valley wash and alluvium.

Geologic structure.—The strata in the Osage Reservation have a general westerly dip that averages about 30 feet to the mile. Actually the beds are bent or folded, particularly in the eastern and southern areas, into many relatively small, shallow depressions and low elevations that vary greatly in form and size and apparently have little regularity or system of arrangement. Most of these buckles or folds are not long enough in proportion to their width and are not sufficiently parallel to be described as "waves" in the beds, as will be seen by a glance at the maps.

The folding or bending of the beds is more marked on the "east side" than throughout most of the "west side" except in the southeast corner. In fact, well-developed folds are comparatively few on the "west side" and largely on this account it is probably far less important as a source of petroleum than the "east side." The increasing depth to the lower sands toward the west further detracts from the relative value of the "west side." The southeastern portion of that side will probably be found to be the best oil territory.

The faults in this region are, in general, few and of relatively slight displacement. They offer evidence of torsional stresses, mainly from the southeast. It is probable that most of them affect but little the amount of oil in the anticlines or domes.

Additional and more detailed information as to the general character of the country and its geologic features will be found in the reports by Mr. Heald on the Foraker and Pawhuska quadrangles[1] and in the valuable report on petroleum and natural gas in Oklahoma published by the State Geological Survey.[2]

The unit area treated in the following papers is the township, which, to permit greater detail in the delineation of key rocks and structure and greater accuracy in the location of the wells, is mapped (without topographic contours) on the scale of approximately 2 inches to the mile. The stratigraphic descriptions are confined mainly to the exposed key rocks, their intervals, convergence, etc., and the known or expected oil sands. The key rocks used in determining the structure in the township are shown only by lines marking the outcrop of the particular horizon—the base, the top, or a characteristic and easily recognized layer—used as the datum plane.

Use of structure contours.—The structural features—that is, the domes, anticlines (upward folds), synclines (downward folds), and folds of other types and the faults—are shown on the maps by "structure contours." Each contour represents an imaginary line on the surface of an inclined rock stratum, connecting all points of that surface that have the same elevation. This elevation is noted

[1] Heald, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey Bull. 641, pp. 17–47, 1917; Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 57–100, 1918 (Bull. 691–C).

[2] Petroleum and natural gas in Oklahoma: Oklahoma Geol. Survey Bull. 19, 2 pts., 1917.

in terms of distance above or below some assumed datum—for example, sea level.

If the rock stratum could be stripped bare and one were to walk along the path indicated by a contour line, he would go neither uphill nor down. The difference in elevation indicated by any two succeeding contour lines is uniform. Thus the successive contour lines may represent distances of 10, 20, 30, 40 feet, etc., above or below the datum plane, and the difference in elevation (in this case 10 feet) marked by adjacent contour lines is the "contour interval." Where the contour lines are close together the slope of the contoured bed is steep; where they are far apart the slope is gentle. Accordingly these lines show with approximate accuracy, by their direction and spacing, the location, shape, extent, and height or depths of the folds or wrinkles in which the strata are bent.

In order to make easier the distinction between domes and sags, or local depressions, the contour lines indicating the sides of the depressions are hachured (marked with short lines on the inner side). However, an inspection of the numbers giving the elevations of the contours at once shows the progress and amount of the rise or depression of the rock surface, the height of the anticline or dome and the depth of the syncline or trough. A structure contour that passes all the way (closes) around an anticline or dome shows that the strata dip away from the axis in every direction—that is, the structure is "closed." Closing contours indicate anticlinal or (if hachured) synclinal structure. The term "closure" indicates, for a dome or anticline, the vertical distance between the lowest point on the fold through which a closing contour would pass and the highest point on the fold; for a syncline, just the reverse. It is usually stated as the vertical distance between the highest and lowest closing contours actually shown on the map, plus the contour interval, and is assigned to the side on which the next lower contour (on an anticline or dome; next higher on a syncline) would not close. For example, if the contour interval adopted is 10 feet, if the distance between the highest and lowest closing contours on a dome is 30 feet, and if the next lower contour would not close on the east the dome is said to have a closure of 40 feet on the east.

Errors in structure mapping due to convergence of strata.—It may happen that two geologists, mapping adjoining areas, have based their structure contouring on key beds which are not extensive enough to furnish a good tie between the two areas. One may have confined his work almost entirely to a higher series, while the other has worked almost entirely on a lower series, so that discrepancies may be found in the structure contouring if the two series are not parallel—that is, if they converge in any direction. Over most of the area allowance has been made for such convergences as have been detected, but there are a few localities where the extent and direction of the convergence can only be surmised. Under such circumstances any attempt to modify the structure mapping by one geologist on a higher series to make it conform exactly with that done by another on a converging lower series is not justifiable. Accordingly, in certain areas there is not an absolute tie between the contours drawn by different observers, although everywhere the contours represent the geologic structure shown by the most readily traceable outcropping beds. To insure continuity in the structure contouring throughout several townships, some conveniently practicable datum plane, assumed to be parallel to the exposed strata, is chosen for the whole area considered, and the readings on the key rocks are projected to and plotted on this plane, which may be above or below the key rocks actually surveyed in the different townships.

Toward the west, where successively younger formations cover the principal oil sands more deeply, these sands are less likely to be parallel to the exposed strata on account of unconformities and convergences due to slight deformation or uplift of the rocks at different intervening stages. Hence the structure as interpreted from the exposed beds may depart more widely from that of the deep sands than it does farther east, where the sands lie nearer to the surface.

Evaluation of geologic structure.—The discussions of the structure are confined to those practical questions which are most important to the oil prospector. The conclusions advanced with respect to the merits of the folds represent the best judgment of the geologists as to the promise of oil and gas and as to the positions and depths of the sands from which production is expected. Nevertheless, it should always be remembered that notwithstanding the general productivity of the anticlines and domes, or, conversely, the relative rarity in this region of really favorable folds that are totally barren, only the drill can determine the ultimate question as to whether oil is actually present at any locality. Sands may be lenticular, tight, or even absent; anticlines in deep sands may not conform in position or form to those in the exposed beds; and possibly other features unobserved or not yet understood by the petroleum geologist may cause disappointment to the prospector.

The recommendations as to points favorable for initial wells to test undrilled areas are to be regarded as suggestions offered with the explicit understanding that dry holes at these places will not condemn the folds. Other tests at points rather less favorable theoretically may bring success, as in sec. 17, T. 25 N., R. 11 E. Even in regions where, as in the Osage Reservation, most of the oil pools are associated with anticlines or domes, few of them occupy the whole of the promising area of the fold. This circumstance appears in most places to be due to irregularity in the sand or lack of continuity of the pay streak or to faulting which may have escaped discovery.

New oil reserves in Mississippian sands.—Both great economic importance and unusual geologic interest attach to the occurrence of oil in sands of Mississippian age in northeastern Oklahoma. Though some doubt exists as to whether the "Mississippi lime" is Boone or Pitkin, the important fact, emphasized by the writers of the following papers, is that oil is found at two or more horizons below the top of the Mississippian series. This fact, now generally recognized, points toward the discovery of new oil reserves in deeper sands be-

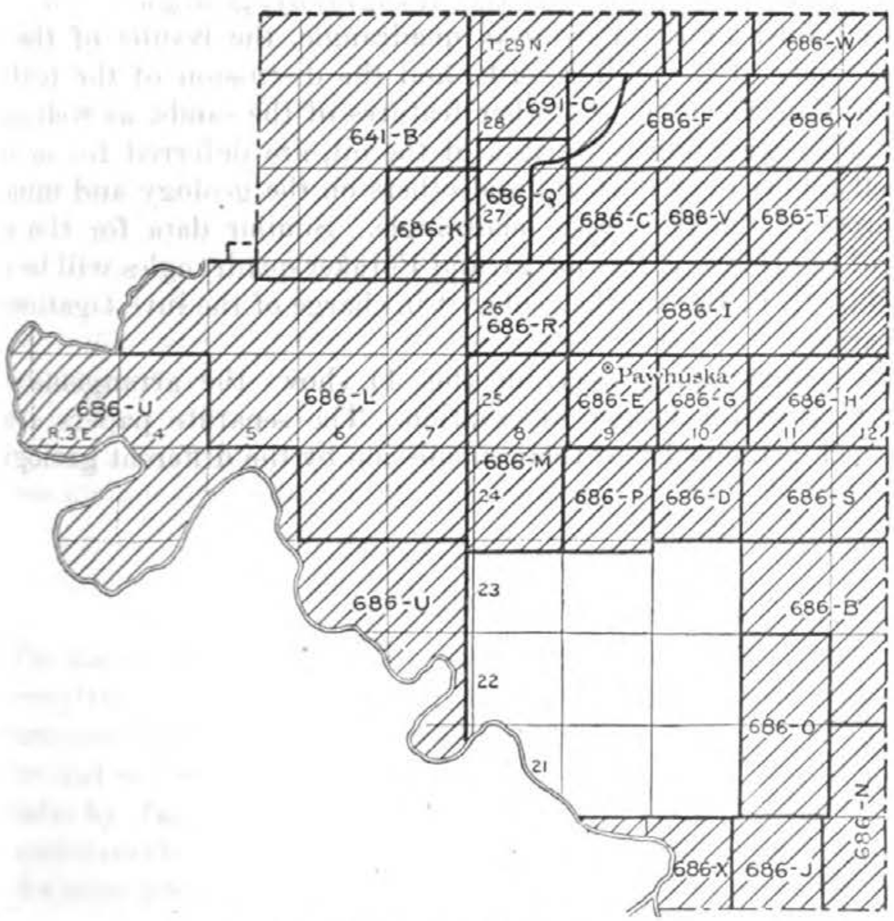


FIGURE 1.—Key map of Osage Reservation showing areas discussed in this and previous bulletins of the United States Geological Survey.

neath some of the producing pools, not only of the Osage Reservation but of the regions to the east, north, and south of it. Attention may be drawn also to the fact that the Sylamore (Devonian) sandstone, though patchy and local in its area of known development, may be present in portions of the oil field in this region. If present it offers oil possibilities, and it should be sought at a few points where anticlinal structure is strongly developed.

Publication of full reports.—Some of the townships in the Osage Reservation have already been described with particular reference to their oil resources in the bulletins of this Survey, as already noted and as indicated in Plate I. These will not be described in this volume. The townships lying west of R. 11 E. in the Hominy quadrangle are now being examined by Robert H. Wood and, together with the remainder of the quadrangle, will be fully described in a bulletin now in preparation by Mr. Wood. In the geologic mapping of this quadrangle the Oklahoma State Geological Survey has cooperated.

The detailed description of the stratigraphy, geologic history, and physiography of the Pawhuska quadrangle, the results of the detailed study of the well records, and the discussion of the texture, composition, porosity, and other features of the sands, as well as of questions concerning the origin of the oil, are deferred for a more formal report by Mr. Heald and others on the geology and mineral resources of the Pawhuska quadrangle. Similar data for the area west of the Hominy, Pawhuska, and Foraker quadrangles will be prepared by C. F. Bowen, the geologist in charge of the investigations in that area.

The accompanying diagram (fig. 1) shows the arrangement of townships in the Osage Reservation. The separate papers are to be issued in the order of their submission by the different geologists.

T. 23 N., R. 11 E.; TPS. 22 AND 23 N., R. 12 E.

By Wilson B. Emery.

INTRODUCTION.

The townships here described lie in the eastern part of the Osage Nation. (See fig. 1.) They include the towns of Avant and Skiatook, on the Midland Valley Railroad, which follows the valley of Bird Creek, a stream with rather broad alluvial bottoms that are devoted to farming. Much of the area consists of wooded ridges traversed by poor roads and little cultivated.

Field work in these townships was done between October, 1917, and February, 1918, by R. H. Wood, O. B. Hopkins, D. E. Winchester, C. S. Ross, P. V. Roundy, and the writer. The area mapped by each geologist is shown in the diagram inserted on Plate II. This diagram shows also the areas surveyed by different methods. Mapping by barometer and compass traverse is less accurate than plane-table work but when carefully checked, as in the present case, affords in the main a true representation of the actual structural conditions.

STRATIGRAPHY.

EXPOSED ROCKS.

The rocks exposed at the surface in this area belong to the middle Pennsylvanian. They comprise a series of sandstones, shales, and limestones, aggregating about 550 feet in thickness, and their character and succession are shown graphically in figure 2. Shale constitutes by far the larger portion of the exposed rocks, though there is considerable sandstone. Except for the Avant limestone, which is the most prominent and readily distinguishable bed in the region, limestone forms a very minor part of the exposed section.

No complete description of the stratigraphy will be given in this paper, but for the convenience of those who wish to do detailed geologic work in this region a few of the most prominent beds or key rocks will be described below.

Avant limestone.—The Avant limestone crops out through Tps. 22 and 23 N., R. 12 E. (See Pl. II.) At the quarry along the railroad between Avant and Oil City the Avant consists of 39 feet of fossiliferous massive gray limestone, overlain by 6 feet of thin platy limestone composed largely of fragments of crinoid stems and Bryozoa. The platy limestone maintains its thickness and character wherever exposed, but the massive limestone thins toward the south and west, and near the east quarter corner of sec. 9, T. 22 N., R. 12 E., it is only 18 feet thick. The Avant rests unconformably on the underlying shale, but as the top of the formation, which remains con-

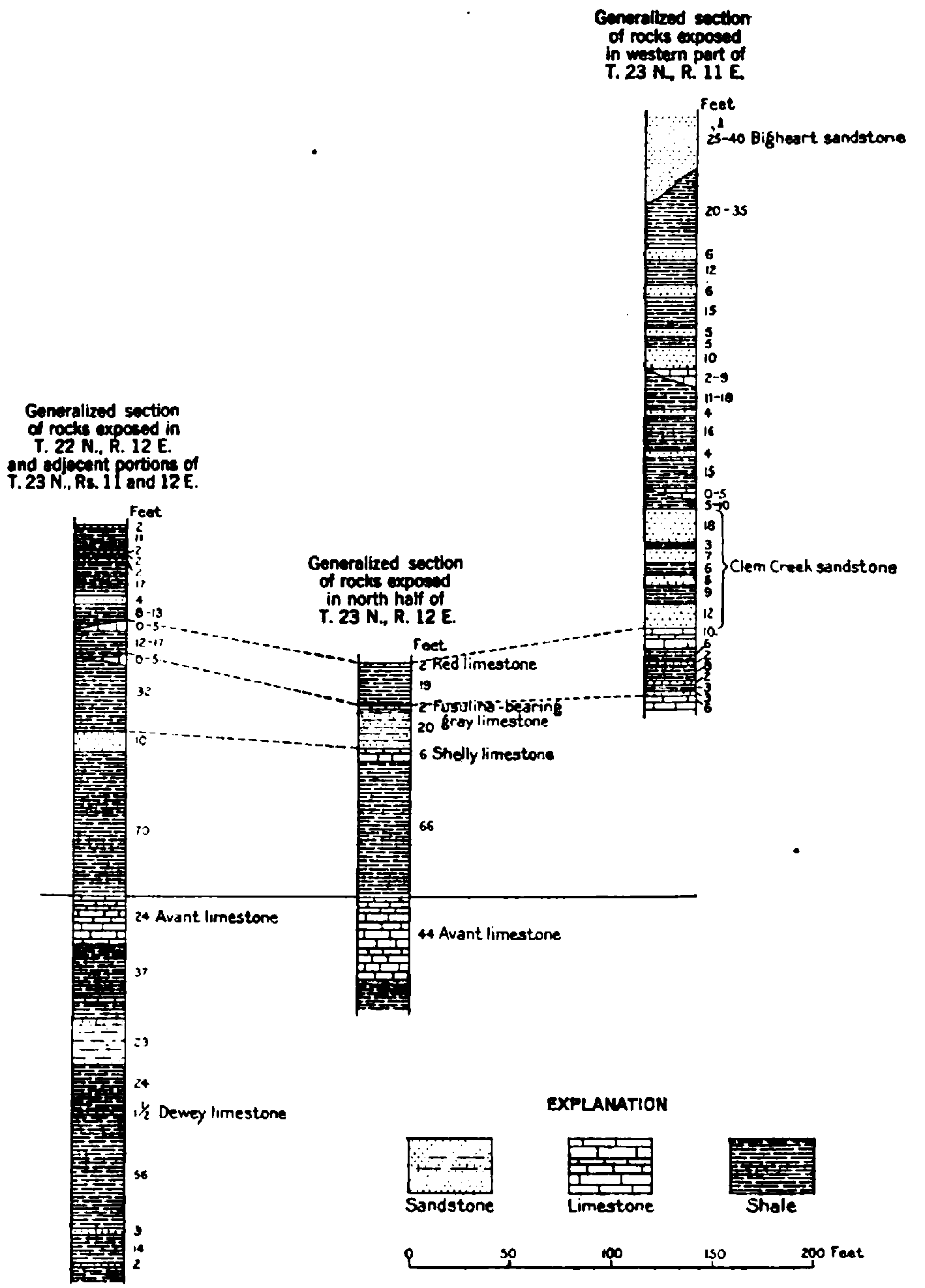


FIGURE 2.—Columnar sections of rocks exposed in T. 23 N., R. 11 E., and Tps. 22 and 23 N., R. 12 E.

stant, was used as a datum in the field work the unconformity at the base does not affect the mapping of the structure.

Fusulina-bearing gray limestone.—The *Fusulina*-bearing gray limestone crops out near the top of the hill south of Avant, in the

N. ½ sec. 18, T. 23 N., R. 12 E., and is well developed in the western part of this township and the eastern and northern parts of T. 23 N., R. 11 E. It is 2 to 5 feet thick and is dark gray on fresh fracture, but weathers into light-gray slabs. Weathered faces are dotted with innumerable *Fusulina* shells which resemble wheat grains. It lies from 95 to 100 feet above the top of the Avant limestone in the northern part of T. 23 N., Rs. 11 and 12 E., but in the southern part of these townships it is about 117 feet above the Avant. The *Fusulina*-bearing limestone was noted only here and there in T. 22 N., R. 12 E.

Shelly and red limestones.—About 20 feet below the *Fusulina*-bearing limestone in the region of Avant is a shelly limestone (see columnar section, fig. 2) which is a helpful stratigraphic indicator. In the southern part of T. 23 N., R. 12 E., this lower limestone grades into and is replaced by a heavy sandstone which forms the first topographic bench above the Avant limestone. From 20 to 30 feet above the *Fusulina*-bearing limestone is another thin limestone (the red limestone of the columnar section) which generally weathers vermilion and which also is a good marker.

Clem Creek sandstone.—The beds here designated Clem Creek sandstone embrace a series of massive medium-grained sandstones and thin lenticular shales aggregating 60 to 65 feet in thickness and are exposed along Clem Creek in the northwestern part of T. 23 N., R. 11 E. This formation is limited below by the red limestone already mentioned, and its upper limit is the top of a massive bed of sandstone 18 feet thick, which is marked by a line of woods at the base of a grass-covered prairie, developed on the overlying shale. This upper sandstone may be conveniently seen along the road in sec. 5, T. 23 N., R. 11 E., north of Clem Creek. Locally near the base of the overlying shale is another thin limestone that weathers red and is a very definite horizon marker. The top of the Clem Creek sandstone was mapped across T. 23 N., R. 11 E., as is shown on Plate II. It lies about 195 feet above the top of the Avant limestone.

Bigheart sandstone.—The name Bigheart sandstone was used by Snider[1] for a series of 175 feet of sandstone and shale exposed at and near the town of Bigheart, in T. 24 N., R. 11 E. The name Bigheart sandstone is here restricted to the basal massive sandstone of this series. In the area covered by this report 40 feet of this sandstone is present, and a typical exposure may be seen near the center of sec. 6, T. 23 N., R. 11 E. It forms a very distinct bench and is notably coarse, the lowest beds being conglomeratic. In places the conglomeratic beds are highly calcareous and weather rusty brown. Because of its slight induration the Bigheart readily crumbles into soft sand. The beds between the Bigheart and the top of the Clem

[1] Snider, L. C., Preliminary report on the clays and clay industry of Oklahoma: Oklahoma Geol. Survey Bull. 7, p. 221, 1911.

Creek sandstone consist principally of shale with minor quantities of thin sandstone. Directly underlying the Bigheart in T. 23 N., R. 11 E., is a gray shale from 20 to 35 feet thick. Locally the upper 6 feet of this shale is red. The base of the Bigheart lies from 345 to 360 feet above the top of the Avant limestone in this area.

ROCKS NOT EXPOSED.

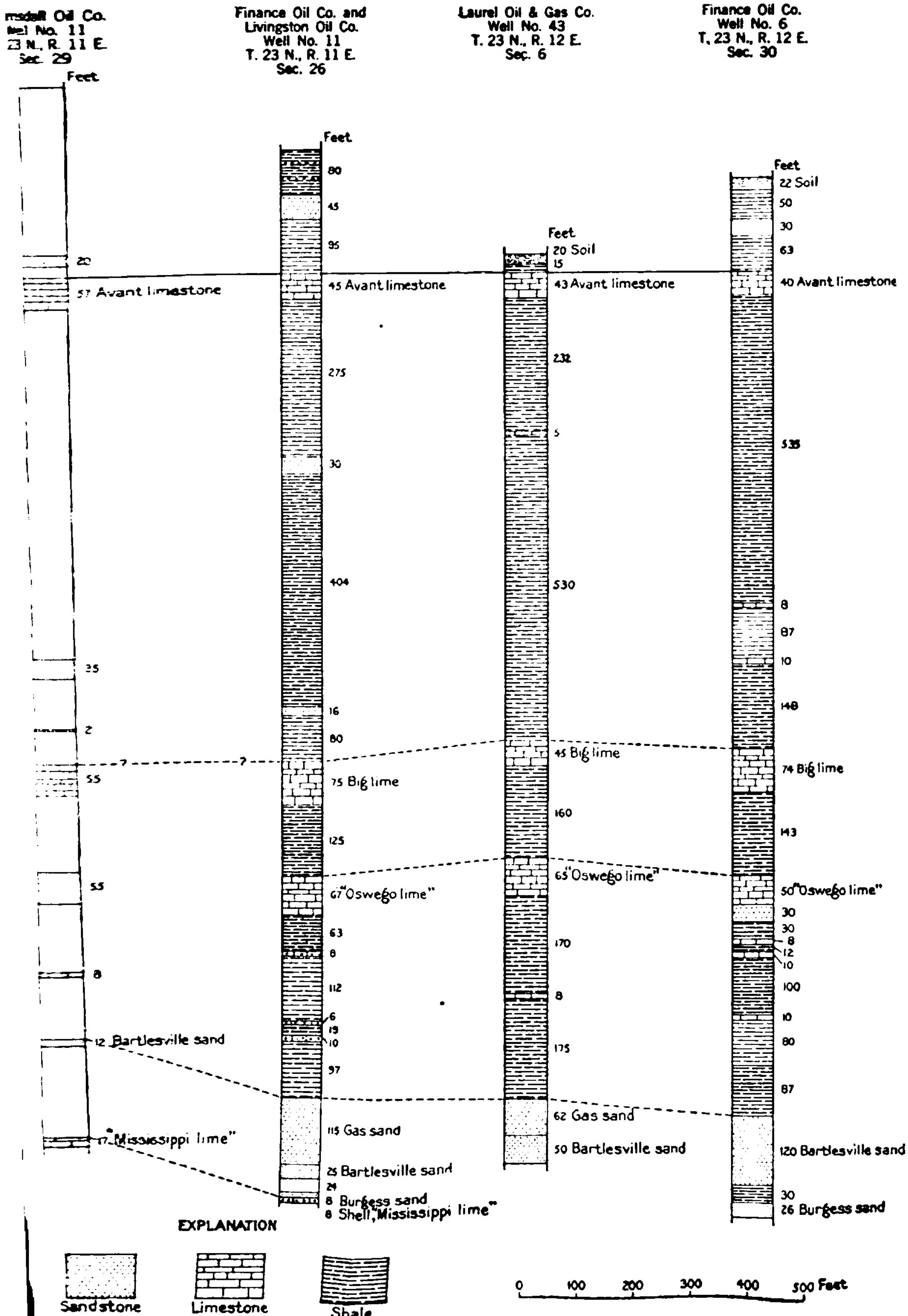
A study of well logs shows that between the surface beds and the productive oil and gas zone in this area lie sandstone, shale, and limestone, and that the shale aggregates many times the thickness of the limestone and sandstone. This is clearly seen in Plate III, on which are shown graphically the rocks reported in the logs of wells drilled at several places in this area.

The first easily recognizable bed below the Avant limestone reached by the drill is a limestone 50 to 75 feet thick, usually called the Big lime by the drillers. It lies about 810 feet below the top of the Avant in sec. 6, T. 23 N., R. 12 E., and 870 feet below in sec. 29, T. 23 N., R. 11 E. The intervening rocks consist almost entirely of shale. Below the Big lime is 125 to 160 feet of shale, followed by a limestone 50 to 65 feet thick. This is named the "Oswego lime" by the oil men and lies 1,015 to 1,050 feet below the Avant. It is underlain by 300 feet or more of shale, containing one or more thin limestone beds, beneath which are a series of sands which contain the productive oil and gas zones of the district.

The top of the productive sandy series lies from 1,350 to 1,450 feet below the top of the Avant limestone. Gas is commonly encountered in the upper 50 to 125 feet of the series, and in places the gas sand is separated from the underlying oil-bearing sands by 25 to 100 feet of shale, but in other places there is no shale between the gas and oil-bearing parts of the series. The oil-bearing sand aggregates 120 to 150 feet in thickness in this region.

Any sand productive of oil in this zone is commonly referred to as the Bartlesville sand, but it may or may not be the same as the productive sand at Bartlesville. The fact, however, that the Bartlesville sand near Bartlesville lies about 1,350 feet below the top of the Avant limestone lends color to the supposition that the sands in the two localities occupy similar stratigraphic positions. About 150 feet below the top of the Bartlesville is in places a thinner oil-bearing sand known as the Burgess sand, and other thin sands are present locally. The entire series of sands, including the gas sand, are probably best regarded as associated parts of the Bartlesville sand, which in this region embraces the basal portion of the Cherokee shale—that is, of the Pennsylvanian.

A few wells in this area have reached, beneath the Bartlesville and associated sands, a limestone generally known as the "Mississippi



SELECTED WELL RECORDS IN T. 23 N., RS. 11 AND 12 E.

lime." The thickness of this limestone is not known, for it has not been completely penetrated. It may represent the Boone limestone of northeastern Oklahoma and southeastern Kansas, but without more detailed information than is now at hand such a correlation can not be definitely asserted. At several localities in eastern Osage County beds below the top of this limestone have yielded oil in commercial amounts, and no well should be regarded as constituting a complete test of a district unless it penetrates the "Mississippi lime" to a depth of 300 feet.

STRUCTURAL FEATURES.

AREAS OF FAVORABLE STRUCTURE.

This area is a portion of a much larger region in which the general dip is northwesterly. The presence of an easterly dip is therefore significant, for it indicates an upfold which may yield commercial quantities of oil. The rocks in T. 22 N., R. 12 E., dip gently northwest with few irregularities, in conformity with the regional structure. Beyond, in T. 23 N., R. 12 E., and the southeastern part of T. 23 N., R. 11 E., is a broad zone of large open folds, and to the northwest, in the northwestern part of T. 23 N., R. 11 E., is a zone of closer folding. There are few faults in these townships. The structure is shown on the map (Pl. II). The contours are based solely on surface data and are drawn on a theoretical bed 500 feet below the top of the Avant limestone.

The largest upfold is the Avant anticline, south of the town of Avant, which affects the attitude of the rocks over a number of square miles in the southwestern part of T. 23 N., R. 12 E., and the southeastern part of T. 23 N., R. 11 E. The crest of the anticline in the SW. ¼ sec. 30, T. 23 N., R. 12 E., is outlined by the 340-foot contour. The lowest closed contour is the 280-foot, giving a closure of more than 60 feet, effective over a roughly circular area of about 4 square miles. Beyond this area anticlinal noses radiate irregularly, as for example in secs. 31 and 20, T. 23 N., R. 12 E. There is also a broad plunging fold in sec. 19, T. 23 N., R. 12 E., and similar folds occur in secs. 23, 24, and 36, T. 23 N., R. 11 E. In the NW. ¼ sec. 35, T. 23 N., R. 11 E., and the SW. ¼ sec. 31, T. 23 N., R. 12 E., are the crowns of two subsidiary domes on the flanks of the major fold. Although both these domes are low on the flank of the large anticline, they offer promise as prospective oil territory, especially the dome in sec. 35, T. 23 N., R. 11 E., which has a very steep dip on the west, toward the bottom of a large syncline. In sec. 18, T. 23 N., R. 12 E., the dip is so low as to make the structure therein effect that of a terrace.

The Avant anticline is cut on the south by a fault which trends southeast and crosses the south line of sec. 30, T. 23 N., R. 12 E., about a quarter of a mile west of the southeast corner of the section.

(See Pl. II.) As the maximum throw of this fault is but 15 feet, it probably has had no important effect on oil accumulation.

A synclinal axis trends northeast from the southeast corner of sec. 31 to and beyond the southwest corner of sec. 21 and limits the anticline on the southeast. At the nearest point the axis of this syncline is a little more than a mile from the crest of the Avant anticline. On the west the rocks dip west for more than 2 miles from the anticlinal crest to the bottom of a synclinal depression which extends north through secs. 34, 27, 22, and 15, T. 23 N., R. 11 E. A synclinal axis extending southeast from sec. 2, T. 23 N., R. 11 E., to sec. 17, T. 23 N., R. 12 E., in a general way following the alluvial valley of Bird Creek, limits the Avant anticline on the north and northeast. The axis of this syncline is 2 to 3 miles from the crest of the Avant fold.

The Avant fold has already been considerably drilled, and the presence of petroleum in it has been thoroughly demonstrated. A consideration of the structure indicates that the productive area may be extended somewhat to the south and southeast in secs. 29, 30, 31, and 32, T. 23 N., R. 12 E., and to the west and southwest in secs. 26, 35, and 36, T. 23 N., R. 11 E. Locations which the writer believes favorable for test wells are indicated on Plate II in secs. 23, 34, and 35, T. 23 N., R. 11 E., and sec. 31, T. 23 N., R. 12 E. The productive sand which such holes will seek is of course the Bartlesville, but if these holes are to be complete tests they should be drilled at least 300 feet below the top of the "Mississippi lime," which is totally untested in the Avant anticline. Beds below the top of the "Mississippi lime" have been found productive of oil in certain other parts of Osage County, and if oil is encountered in commercial quantity in them in these tests an extensive oil reserve beneath the Avant anticline may confidently be expected.

A second prominent upfold in the area is the Candy Creek anticline, in the northeastern part of the fractional T. 23 N., R. 12 E., east of the town of Avant. The axis of this anticline extends north near the west line of sec. 15 into sec. 10, where it turns sharply to the east. The 330-foot contour closes east of the edge of the mapped area and, owing to the sharp change in strike, this contour outlines a boot-shaped area, which is about half a square mile in extent. This anticline has two crowns, one in the NW. ¼ sec. 15 and the other in the SW. ¼ sec. 10. Both crowns are outlined by the 340-foot contour. In sec. 3 a small fault with a throw of less than 10 feet cuts the beds in a direction a little west of north but has probably had no effect on oil accumulation. In the western part of sec. 9 there is a small subsidiary anticline. The 290-foot contour is the lowest closed contour around this secondary fold, which is separated from the main fold by a small shallow syncline. The main anticline is limited on the west by a rather broad syncline, the axis of which in a general way follows the alluvial valley of Bird Creek. A sharp northward-trending syncline near the county line in sec. 15 limits the anticline on the southeast.

The value of the Candy Creek anticline as oil territory has been demonstrated. Consideration of the structure leads to the conclusion that the beds on this fold may be expected to be productive from the east border of Osage County westward down the dip as far as the beds now producing in the two west tiers of sections in the township.

In the S. ½ sec. 7, T. 23 N., R. 11 E., is the crown of the Hardy dome, which has a closure of more than 40 feet and includes a delta-shaped inclosed area of about 1½ square miles, though the rocks are upfolded over a considerably larger area. A small secondary dome occurs on the flank of the major dome in the E. ½ SW. ¼ sec. 8, T. 23 N., R. 11 E. The major dome is limited on the east, north, and south by synclines whose axes lie about a mile from the crest, but to the west the synclinal axis lies more than 1½ miles distant. Recent drilling on the crown of the Hardy dome has resulted in the bringing in of gas wells of considerable size. The flanks of the dome have not yet been tested, but there is every reason to expect that oil in commercial quantities will be encountered. The west flank appears especially favorable, and it is possible that oil will be obtained for some distance down this flank in T. 23 N., R. 10 E.

Southeast of the Hardy dome is a narrow anticline, the Lombard anticline, the axis of which extends north and northeast from the NW. ¼ sec. 28 through the central part of sec. 21 into the SE. ¼ sec. 16, T. 23 N., R. 11 E. The 170-foot contour is the lowest closing contour around this anticline, and as the crest of the fold is outlined by the 200-foot contour, there is a closure of over 30 feet. The inclosed area, which is cucumber-shaped, amounts to about 1 square mile. The anticline has two crowns, one in the NE. ¼ sec. 21 and the other just south of the center of the section, separated by a saddle over 10 feet deep. On the southwest this anticline merges with a northwestward-dipping monocline, and on the north it plunges into a faulted syncline. The regular northwest dip of the west flank is interrupted by an attenuated anticlinal nose extending northwest from the southeast corner of sec. 20 to and beyond the northwest corner of the section. On each side of this nose a syncline extends east and southeast toward the main uplift. The anticline is limited on the southeast by a rather broad syncline which trends northeast. The axis of this syncline is in places less than half a mile from the crest of the anticline. In the writer's opinion the Lombard dome has excellent possibilities as prospective oil territory. Test wells in the SE. ¼ sec. 16 or the SW. ¼ sec. 21, in places shown on the map or at any point between these places, will be favorably located structurally. If oil is found the productive beds may reasonably be expected to extend far down the anticlinal nose that trends northwestward through sec. 20.

Just south of the north quarter corner of sec. 33, T. 23 N., R. 11 E., is the crown of the Brown anticline, which has a closure of more than 30 feet and an inclosed area of about 1½ square miles in secs. 28, 32, and 33. The axis of this anticline trends northeast. On the northwest the beds dip in that direction for more than 2 miles to the bottom of the limiting syncline, but on the east the axis of the complementary syncline is less than a mile distant. This syncline plunges both north and south from a low divide in the major syncline, at the north line of sec. 34, and its southern part is a closed depression more than 30 feet deep. The structure of the Brown fold is very favorable for oil accumulation, and oil in commercial quantity has already been found there.

In sec. 31, T. 23 N., R. 11 E., is the small but well-defined Fox dome, which is a part of a large fold that embraces also the Brown anticline, just described. This dome is separated from the Brown anticline by a shallow saddle, whose axis is less than a mile to the east. The Fox dome is proved oil territory, having yielded oil from sands above the "Mississippi lime." The lower sands also warrant testing.

A broad, low dome, here called the Labardie dome, is present in secs. 3 and 4, T. 23 N., R. 11 E. This fold is cut in sec. 4 by a northwestward-trending fault having a maximum throw of about 20 feet, with the upthrown block on the west side of the fault trace. The Labardie dome is separated by a shallow syncline from a smaller dome, the crown of which is in the extreme northwest corner of sec. 2 and the NE. ¼ sec. 3 of this township. Southeast of these domes is a closed syncline in secs. 2 and 11, and southwest of them another closed syncline in secs. 5 and 8. The major syncline in which both these closed depressions are situated is faulted south of these domes in sec. 9. Of the two faults the western is the larger, having a maximum throw of about 30 feet in the S. ½ NW. ¼ sec. 9. The throw of the other fault is less than 10 feet. Between the two faults the rocks have been folded into a small incomplete anticline flanked on the south by a small closed depression. Structurally this dome does not appear to be particularly favorable as prospective oil territory. A dry hole has already been drilled near its crest.

In the NW. ¼ sec. 4, T. 22 N., R. 12 E., occur two very small domes. These domes are in effect a single structural feature on a larger fold—an anticlinal nose. The writer believes as favorable a site as any other for a test hole is in the NW. ¼ sec. 4, as shown on the map, but a consideration of the structure leads to the conclusion that oil, if encountered, will probably not be found in large amount.

In secs. 9 and 10, T. 22 N., R. 12 E., the general westerly dip of the beds is interrupted by a local flattening that gives rise to a terrace. This is a small structural feature and does not hold much promise as oil territory. The dry hole in sec. 9 was drilled in a structurally favorable location, but as its record is not available it is not known whether or not the hole actually reached all the sands and was an adequate test. Oil has been found in secs. 5 and 8 of this township under less favorable structural conditions, and if the hole already drilled was not a thorough test, further prospecting of this terrace is warranted.

AREAS OF UNFAVORABLE STRUCTURE.

In view of the spotted distribution of the producing wells in this region, it would be hazardous to state that certain structural features in this area are not favorable for oil. It seems extremely unlikely, however, that commercial quantities of oil will be found in the major synclines, such as that in secs. 2, 9, 8, 5, and 6 and that in sec. 19, T. 23 N., R. 11 E. A few small wells were found in sec. 5, but these are now abandoned. It also seems very improbable that oil in economic quantity will be obtained in the deep closed syncline in the southeastern part of sec. 33 and the southwestern part of sec. 34 of the same township. Another unfavorable area is the syncline in sec. 6, T. 22 N., R. 12 E., and adjacent sections.

PRODUCTION.

A study of the records of initial production of wells in T. 23 N., R. 12 E., which is the most thoroughly drilled township in the area (see map, Pl. II) and which may be considered typical of the area, shows that about two-thirds of the wells came in, after being shot, with yields of 50 barrels or less, and that wells with an initial production of over 500 barrels were extremely rare. It is probably safe to make the general statement that in the area here described only small producers may be expected. On the other hand, production continues for a long time, as is evident from the fact that some of the leases in T. 23 N., R. 12 E., have been producing since 1906.

The area of greatest uplift in T. 23 N., R. 12 E., is productive throughout its extent, even the syncline which follows the valley of Bird Creek yielding oil in commercial amounts. The production along the major uplift is spotted and does not appear to follow any general rule. One noteworthy fact is that on the crest of the major Avant uplift only gas has been encountered. For this reason the writer is of the opinion that leases on the crests of broad folds in this region will yield considerable gas. All the anticlines in the area which have so far been tested have, with the exception of the Labardie anticline, yielded oil in commercial amounts.

T. 27 N., R. 9 E.

By Dean E. Winchester.

STRATIGRAPHY.

The rocks exposed in T. 27 N., R. 9 E. (see fig. 1), consist of limestone, sandstone, and shale of Pennsylvanian age (see columnar section, fig. 3). The oldest beds crop out along the eastern edge of the township and comprise red, gray, and yellow shales, thin sandstones, and a single persistent bed of limestone that is correlated with the middle bed of the Oread limestone of the Kansas section. Above this shale series is the Elgin sandstone, consisting of about 175 feet of irregularly bedded sandstones with a few lenses of shale and limestone. The sandstone series crops out along the valleys of Sand, Mud, and Cedar creeks and gives rise to rough, timber-covered areas. Distinctive or persistent beds which may be used as marker beds in mapping the geologic structure are lacking in most of the area. About 125 feet of limestone, shale, and thin sandstones, constituting a series of beds known as the Pawhuska limestone, occur above the Elgin sandstone. The Pawhuska is terminated at the top with two thin beds of "red lime." Limestone and shale give rise to untimbered prairie land, so that the key beds in this series can be easily followed. In the extreme northwest corner of the township are about 100 feet of massive sandstone, shale, and some limestone, which constitute the highest beds exposed in the area.

Key beds that are useful in determining the geologic structure are abundant in the western part of the area but much less so in the middle and eastern parts. The outcrops of three are shown on the accompanying map (Pl. IV). The middle bed of the Oread limestone crops out near the east edge of this township and is very well exposed west of the Pawhuska-Elgin wagon road in the NE. ¼ sec. 36. This limestone weathers as a grayish-white rock, which contains many *Fusulina* and other easily recognizable fossils and in this part of Osage County is about 2 feet thick. In many places the presence of the bed at the outcrop is indicated only by very small fragments of yellowish-white clayey lime or perhaps by a few of its characteristic fossils. The next higher key bed of importance is here named the Plummer limestone member (of the Pawhuska

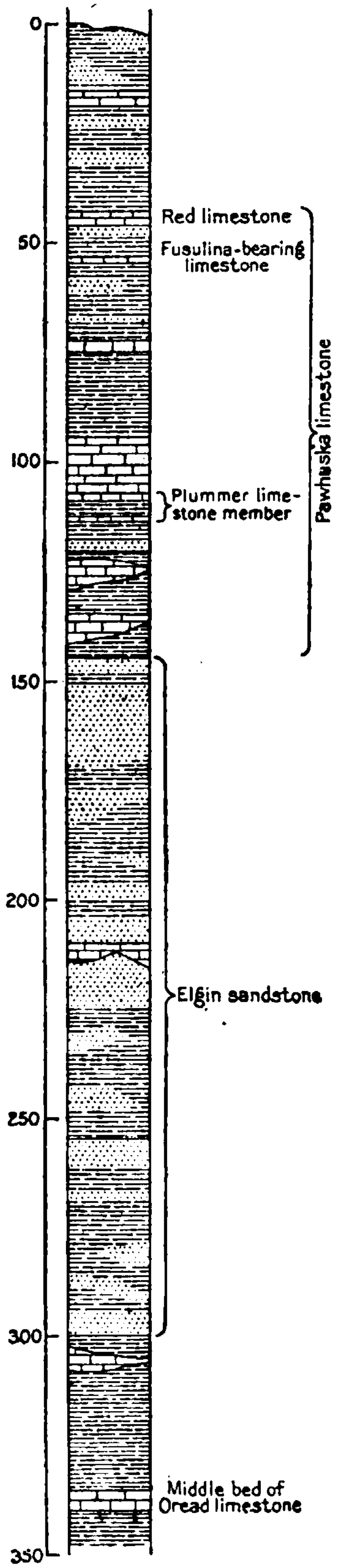


FIGURE 8.—Stratigraphic section showing rocks exposed in T. 27 N., R. 9 E.

limestone) because of its exposures near the house on the Plummer ranch, in T. 26 N., R. 9 E. This limestone is also present on the Myers gas dome, which is just southwest of T. 27 N., near Myers station on the Midland Valley Railway. The Plummer limestone consists of black flinty, angular limestone which is only locally fossiliferous, separated into two benches by 6 to 8 feet of shale. The outcrop of the upper bench of the Plummer limestone, beneath the gray ledge-making limestone of the Pawhuska formation, is usually marked by long, square-edged blocks, only one edge of which is exposed. The lower bench of this black limestone is of much less value as a key bed, and its outcrop is not shown on the accompanying map (Pl. IV). The limestone is well exposed in this township along the road on the south side of Sand Creek in sec. 30. About 15 to 20 feet below the top of the Plummer limestone there is a very persistent sandstone bed about 2 feet thick, which, because of its peculiar ragged manner of weathering, was called the "ragged sandstone" in the field. This is the only resistant sandstone bed in the series and is therefore easily identified, but because of its nearness to the outcrop of the Plummer limestone, its outcrop is not shown on the map. Two thin beds of reddish-gray hard, brittle limestone at the top of the Pawhuska limestone were followed in the field, and the outcrop of the lower of these is shown on Plate IV. At 9 feet below the lower of these red limestones is a very thin bed of limestone so full of *Fusulina* that it resembles a bed of dirty rice. This bed is of great value in correlation, even though it is not everywhere exposed. Good exposures of all these limestone beds are to be found near the southwest corner of sec. 6.

The log of a well drilled in sec. 8 of this township is shown in figure 4 and gives an idea of the character of the rocks which occur between the surface and a depth of 2,300 feet. In drilling in this township sands that may yield oil should be found in at least four zones, namely:

1. A zone about 1,400 feet above the Fort Scott ("Oswego") limestone, as indicated by the show of oil in wells of the Myers gas field and in the well in sec. 8.
2. The Fort Scott ("Oswego") limestone.
3. The Cherokee shale, including a sand supposed to be the Bartlesville sand. Records of deep tests in this part of the county indicate that the sands of this zone are thin or possibly missing.
4. Sands in the upper 300 feet of the "Mississippi lime." The oil produced in the vicinity of Pawhuska, south of this area, comes from this zone.

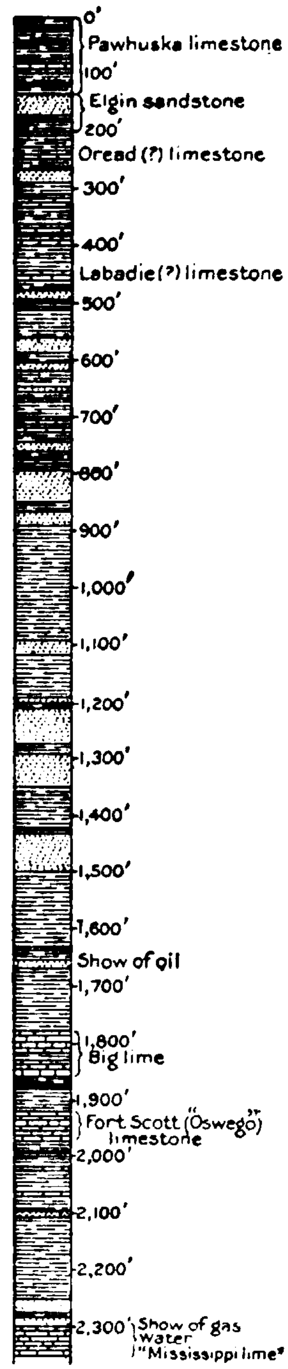


FIGURE 4.—Record of well showing stratigraphic conditions below the surface in T. 27 N., R. 9 E.

STRUCTURE.

The surface structure shown by 10-foot contours on the accompanying map (Pl. IV) was determined by carefully following key beds and accurately determining elevations at short intervals along their outcrops. The contours represent the structure as indicated by the surface beds but are drawn on an imaginary bed which is about 300 feet below the middle bed of the Oread limestone. The rocks over a large part of this township dip gently westward and are not faulted except in the southeastern part, where the beds are badly crumpled and broken. There are, however, several upwarped structural features, as will be noted by reference to the map. These are described in detail below.

Parts of secs. 7, 8, 17, and 18 are included in an irregular-shaped anticlinal fold which has a southeasterly dip of a little more than 20 feet and a closed area of more than a section. This fold is quite large enough to influence the accumulation of oil and is worthy of complete tests. One well drilled near the top of the anticline by the American

Pipe Line Co., which holds the gas lease over this area, did not get oil or gas in paying quantity, although in the log of this well 15 feet of sand is recorded at the general horizon of the Bartlesville. A show of oil is reported in sands above the Fort Scott limestone ("Oswego lime"), but the sands at the horizon of the Bartlesville sand are reported to be dry, both of oil and water. It is not impossible that this well penetrated the oil sand at a point where the sand was too tight to yield its oil, even if it contained any, and that had the well been shot some oil might have been obtained. In any event the anticline should not be definitely classed as unproductive until at least one other well has been drilled and the "Mississippi lime" has been penetrated at least 300 feet. The presence of even a trace of oil in any sand should be sufficient evidence to call for the shooting of the sand in order to prove its possibilities. To thoroughly test the anticline wells should be drilled near the centers of the NW. ¼, NE. ¼, and SE. ¼ sec. 7.

In secs. 30 and 31 there is an area showing anticlinal structure with a closure of at least 30 feet and a closed area of about a section which seems excellently suited to bring about the formation of an oil pool. This uplift has the shape of an elongated dome whose longer axis trends north and south and which is separated from the Myers gas field dome to the south by only a low saddle. Several wells drilled on this dome by the American Pipe Line Co., the holder of the gas lease, have produced considerable gas, but the records of these wells show no oil, although one or more of them were drilled to the "Mississippi lime," below most of the sands which have been found productive of oil in Osage County. The area should not be finally condemned as oil territory until at least one well has penetrated the sands below the top of the "Mississippi lime," which are the source of the oil in the wells near Pawhuska. The gas obtained from this dome comes from sand above the Fort Scott ("Oswego") limestone, and only one or two of the wells have been drilled deeper. The records of deep tests on this dome show little or no sand at the horizon of the Bartlesville. The oil-producing possibilities of the dome can probably best be tested by drilling on its flanks west of this township, near the east line of sec. 36, T. 27 N., R. 8 E.

A small dome in secs. 11 and 14 is part of a long nose on the west side of a large fold in the township to the east. Although the dome itself has a closure of only a single contour its value is considerably greater than this would indicate, because of the fact that it is part of the larger fold. This dome should act as an accumulating ground for petroleum, as there is a very large area to the west and northwest from which the oil might be derived. It would appear that the W. ½ sec. 11 and the N. ½ sec. 14 are worthy of complete tests.

A small anticline, whose high point is near the center of the east line of sec. 21, shows but a single closing contour, but a long nose projecting to the west from a point near its south end adds considerable value to it and justifies its thorough testing. Wells drilled in the NW. ¼, near the northwest corner of the SE. ¼, and along the north line of the SW. ¼ will prove the value of this anticline as a source of oil.

Owing to the generally disturbed condition of the rocks in the southeastern part of the township this area is recommended as a probable source of oil. There is evidence of general anticlinal structure near the west line of sec. 25, and this locality is probably worthy of testing. Evidence seems to indicate that wells near the northwest corners of secs. 25 and 36 will test the area best. The faults shown on the map seem likely to prove a barrier and prevent the migration of oil to the small elongated anticline near the east line of sec. 36.

Areas of synclinal or monoclinal structure are considered generally unfavorable for oil accumulation, especially in the Mid-Continent field, but underground features, such as the presence of lenticular sands, may provide suitable conditions for the formation of an oil pool. Such pools can be located only by pure wildcat drilling.

T. 24 N., R. 10 E.

By C. F. Bowen.

STRATIGRAPHY.

EXPOSED ROCKS.

General character.—The rocks exposed in T. 24 N., R. 10 E. (see fig. 1) are illustrated graphically in figure 5. They have an aggregate thickness of about 550 feet and belong stratigraphically in the upper part of the Pennsylvanian series. They consist mainly of alternate beds of sandstone and shale, with two well-defined limestones near the base of the section, two thin limestones about 100 feet below the top, and local lenses of limestone at other horizons.

The sandstones are for the most part medium-grained quartzose rocks but vary in composition and physical features and are irregular and inconstant in thickness and extent. The shales are prevailingly red, but, as shown in the columnar section, there are two well-marked intervals of gray shale which are valuable guides in tracing the sandstones above them. A detailed discussion of the stratigraphy and the grouping of formations will be given in the final report on the Pawhuska quadrangle. In this report the description is confined to the principal key beds used in mapping.

Key beds.—The exposed rocks include three more or less well-defined key beds, the outcrops of which are shown on the accompanying map (Pl. V). They are, in ascending order, the Birch Creek limestone, the Bigheart sandstone, and the Fourmile sandstone. At the top of the section is another sandstone, 15 to 20 feet thick, named by K. C. Heald [1] the Wynona sandstone, from exposures at and near the town of Wynona, in T. 24 N., R. 9 E.

Birch Creek limestone.—The Birch Creek limestone, named from its excellent exposure in the bluffs on the north side of Birch Creek, near the east edge of the SE. ¼ sec. 25, is well exposed also on the south side of Birch Creek to a point within about a quarter of a mile of the west side of sec. 36, where it passes beneath the surface. Another good exposure occurs in the railroad cut about 1½ miles south of Bigheart, in sec. 19, T. 24 N., R. 11 E. It is a hard light-gray crystalline, somewhat dolomitic limestone and is sparingly fos-

[1] Report on T. 24 N., R. 9 E., in preparation to form a part of Bulletin 686.

siliferous. It contains a considerable percentage of iron, which gives it an unusually high specific gravity and produces a deep rusty-brown color on the weathered surface. Laterally it grades into limy sandstone.

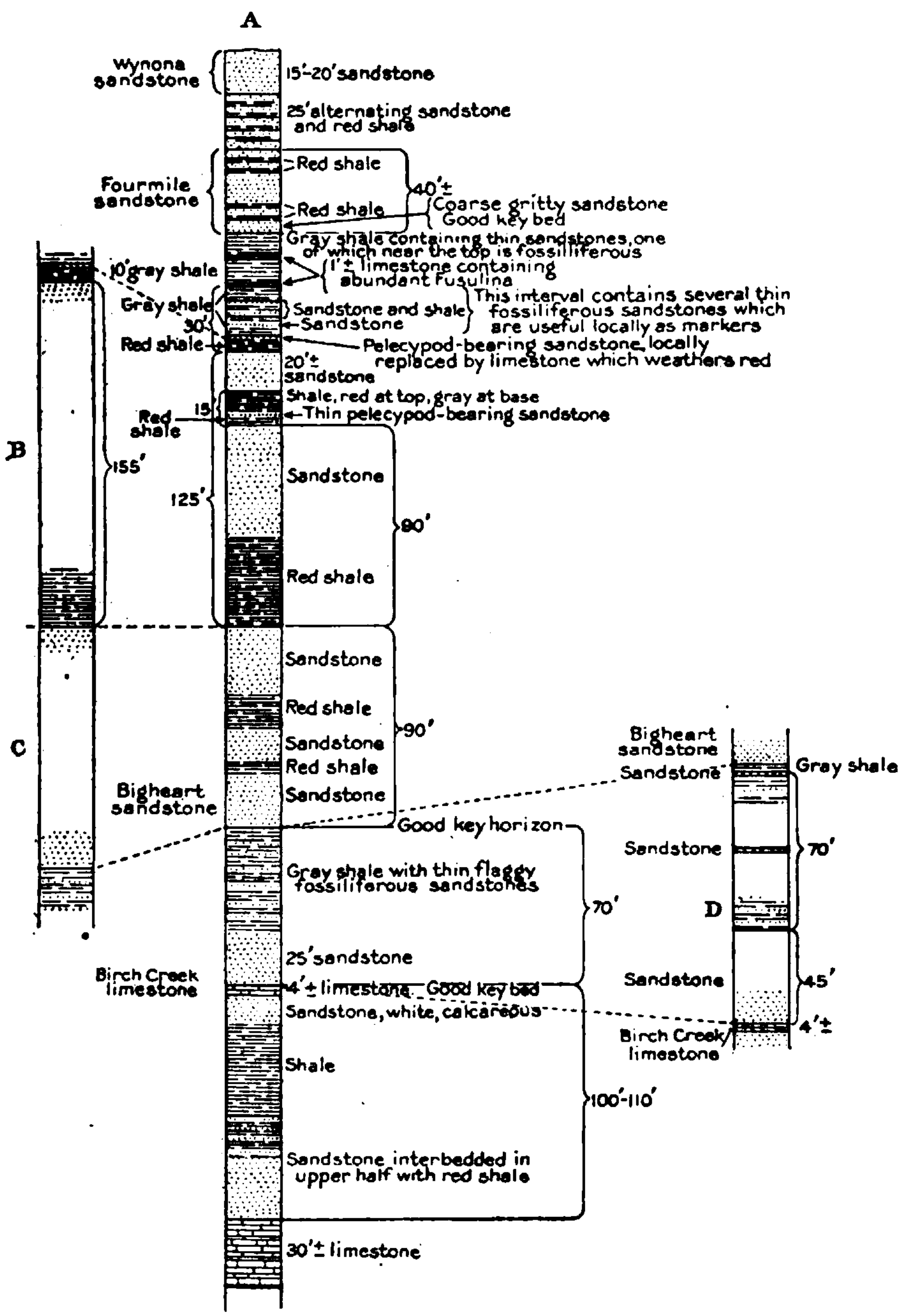


FIGURE 5.—Columnar sections of rocks exposed in T. 24 N., R. 10 E. A, Generalized section; B, section at north side of sec. 24, showing convergence of the beds indicated between that point and the east quarter corner of sec. 22; C, section near the south quarter corner of sec. 14, showing convergence of the beds indicated between that point and the SW. ¼ NW. ¼ sec. 11; D, section in the NW. ¼ sec. 19, T. 24 N., R. 11 E., showing convergence of the Bigheart sandstone and Birch Creek limestone between that point and the SW. ¼ sec. 36, T. 24 N., R. 10 E.

The Birch Creek limestone seems to be at approximately the same horizon as a limestone at Bartlesville believed, but not definitely proved, to be the Stanton limestone. According to O. B. Hopkins,[1] however, the Birch Creek may be as much as 15 feet below the limestone at Bartlesville.

Bigheart sandstone.—From 70 to 115 feet above the Birch Creek limestone is a massive ledge-making sandstone, 25 to 50 feet thick, here called the Bigheart sandstone[2] because it is well exposed at Bigheart, forming the main ledge in the bluffs west of the road between Bigheart and Quawpaw. It is a massive, cross-bedded ledge-making sandstone 25 to 50 feet thick. In some places it consists of a single bed; in others it is separated into two members by a bed of red shale 4 feet or more thick. At its base the sandstone is slightly conglomeratic, and for several feet above this basal part it is very coarse grained or gritty. In this gritty portion the coarse grains of white, red, and black quartz stand out in relief on the weathered surface, in marked contrast to the other sandstones in this part of the section. The conglomeratic portion is rarely exposed, because it disintegrates readily and is also commonly covered by talus or wash. The gritty character of the basal part of this sandstone, together with the fact that it rests on gray shale, whereas the shales higher up in the section are red, make the contact of the shale and sandstone a valuable key horizon. In some places, however, there is a small amount of red shale between the sandstone and the gray shale, but in such places the gray shale can usually be found and there is little difficulty in establishing the horizon. The conglomeratic character of the sandstone is most pronounced in the southern part of the township.

Fourmile sandstone.—About 40 feet below the top of the section and about 350 feet above the Birch Creek limestone is a group of beds consisting predominantly of sandstone, with some interbedded shales near the top and base. These beds, here called the Fourmile sandstone, are well exposed on the point south of Fourmile Creek in the SW. ¼ sec. 30, extending eastward about three-quarters of a mile from the small oil field at the west side of the section. They consist of a massive sandstone about 25 feet thick, overlain and underlain by some thinner sandstones and interbedded red shales, the whole having a thickness of about 40 feet, but this varies considerably from place to place. The basal bed of this sandstone is distinguished from other sandstones in this part of the section by being coarse and gritty, resembling the basal part of the Bigheart sandstone, but it

[1] Report on T. 25 N., Rs. 11 and 12 E., in preparation to form a part of Bulletin 686.

[2] The name Bigheart sandstone was used by L. C. Snider (Oklahoma Geol. Survey Bull. 7, p. 221, 1911) for 175 feet of sandstones and shales supposedly exposed at and near Bigheart, but the term is here restricted to the basal massive sandstone of that series of beds, which is a useful horizon marker over a considerable area.

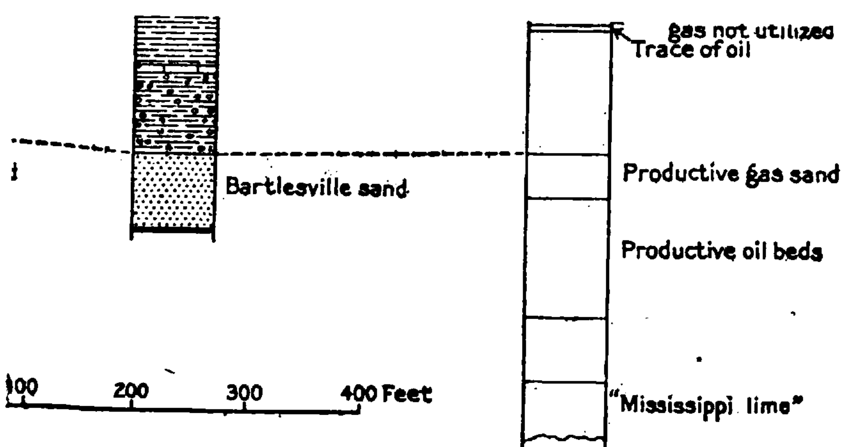
differs from the Bigheart in not being conglomeratic. It is al immediately underlain by gray shale, whereas the other shales in tl part of the section are prevailingly red. The distinctive charact of the sandstone, together with the gray shale below, render this bas bed the most distinctive traceable key bed in the western part of t township. It is however, less distinctive and valuable in the nort ern part of the area than in the southern part. The tracing ar identification of the bed are further facilitated by the presence two thin limestones and a thin fossiliferous sandstone in the sha below it. The limestones are 8 to 10 feet apart, and the upper or is 10 to 15 feet below the base of the Fourmile sandstone. Thes limestones are commonly a foot or less in thickness and are simila in composition, being characterized by an abundance of small *Fusu lina*, with few other fossils. In places they grade into calcareou sandstones characterized by a smooth white weathered surface. Ex posures of these limestones are rare. They are commonly conceale by talus and hill wash from the sandstone above but can be founc in a sufficient number of places to render them valuable as checks or the sandstone. A good exposure of the lower limestone occurs in the bed of Fourmile Creek about 400 feet west of the west boundary of sec. 30.

Between the upper limestone and the base of the Fourmile sandstone there is a thin fossiliferous sandstone which in the northern part of the township contains an abundance of *Fusulina*, but farther south these are replaced largely by pelecypods and brachiopods. The brachiopods serve to distinguish this sandstone from other fossiliferous sandstones lower in the section.

UNEXPOSED ROCKS.

The unexposed rocks and their relation to those exposed at the surface are shown graphically in columns 1 to 4, Plate VI. To a depth of about 1,200 feet below the Birch Creek limestone they are very similar in character to the surface rocks. Between this depth and the "Mississippi lime" limestones become more abundant, two beds of which, the Big lime and the "Oswego lime" (Fort Scott limestone), are commonly recognized by drillers. The position of the oil and gas bearing sandstones with relation to these limestones is shown in column 5, Plate VI.

The principal oil-producing sandstone in this area is generally known as the Bartlesville sand, although it may include more than the Bartlesville sand at Bartlesville. It is 70 to 150 feet thick and in many of the wells is broken in the lower part into several thin beds, to some of which the drillers have given distinctive names, such as Tucker sand and Burgess sand. Gas is commonly found in the upper part of the Bartlesville, the oil in some of the wells not being encountered at [illegible] depth of



SITION OF OIL AND GAS BEARING BEDS IN T. 24 N., R. 10 E.

being encountered until the sand has been penetrated to a depth of 50 feet or more.

About 650 to 675 feet above the Bartlesville and about 275 feet above the "Oswego lime" (Fort Scott limestone) is a thin sand 10 to 12 feet thick which is the source of the oil obtained in sec. 22.

Between the Big lime and the Fort Scott ("Oswego") limestone occur one or more sands or sandy shales. To one or another of these the name Peru sand is commonly applied. In some places this sand contains traces of oil, but it has not been a source of oil in this township. Traces of oil also occur in some places in the "Oswego lime" and the Big lime and in one or more shallow sands 600 feet or more above the Big lime.

The chief source of gas in the township is the upper part of the Bartlesville sand, commonly referred to as gas sand by the drillers. In some places a considerable supply of gas has also been encountered in the "Oswego lime" and in the Big lime. Traces of gas have been found in thin sands between the Bartlesville sand and the "Oswego lime," and also at various horizons from 350 to 1,000 feet above the Big lime. In only one place, however (the North Cochahee dome), are these shallow sands reported to have yielded more than 1,000,000 cubic feet of gas a day.

STRUCTURE.

The rocks in this township have a somewhat steeper westward inclination than is common in other parts of the Pawhuska quadrangle. A belt of especially steep dips crosses the central part of the area in an almost due north direction. The largest anticlines or domes lie east of this belt. The structure contours shown in Plate V are drawn on an assumed datum plane 220 feet below the Fourmile sandstone. The anticlines and domes will be described from east to west, beginning at the southeast corner of the township and progressing westward by tiers of sections.

BIRCH CREEK AND BIGHEART DOMES.

The Birch Creek dome, in secs. 25 and 36, and the Bigheart dome, in the southeast corner of sec. 12 and the northeast corner of sec. 13, lie mainly in the next township to the east. As they are fully described in the report on that township, they will receive only brief mention here.

The Birch Creek dome covers an area of more than 4 square miles and has a closure on the east of about 125 feet. It is therefore one of the largest structural features in the Pawhuska quadrangle. Its crest lies about 1½ miles northeast of the southeast corner of this township. A part of the fold has been well tested in T. 24 N.,

R. 11 E., where the most oil has been obtained on the north slope of the dome and gas has been obtained in several wells drilled near its crest. Along the north side of sec. 25 and in the southwest corner of sec. 26 of the township here discussed dry holes have been obtained well down toward the base of the fold. A hole in the SW. ¼ sec. 25, however, in about the same structural position, obtained some oil, but no record is available of the quantity. In view of previous development the SW. ¼ sec. 25 and all but the west tier of forties in sec. 36 of this township appears to be very promising oil territory.

REDEAGLE ANTICLINE.

The Redeagle anticline lies mainly in secs. 1, 2, 11, and 12 of this township but extends into the SW. ¼ sec. 6 and the NW. ¼ sec. 7, T. 24 N., R. 11 E. The major axis of the anticline is about 2½ miles long and trends somewhat north of east. The maximum width of the fold from north to south is about 1 mile. Near its west end, in sec. 12, there is a slight constriction which gives the anticline a compound structure. The shape and extent of that part of the anticline lying in T. 24 N., R. 11 E., are uncertain because it occupies an alluvial flat in which no key beds are exposed. The crest of the fold lies in that township, and the amount of east dip is apparently slight, not more than one contour closing around the fold. The beds have a gentle westward dip from the highest part of the fold to about the center of sec. 11, from which they drop about 50 feet in the next half mile.

About one-half of that part of the anticline lying in T. 24 N., R. 10 E., has been developed by the Pen Mar, Barnsdall, and Nicaragua oil companies. (See Pl. V.[1]) Out of 45 productive oil wells for which records are available, 5 are reported to have had an initial production of 300 to 1,500 barrels, 11 to have ranged between 100 and 250 barrels, and 28 to have produced less than 100 barrels. The largest yield was obtained from wells near the crest of the anticline, extending from the southeast corner of sec. 11 to the NE. ¼ NW. ¼ sec. 12. About 200 feet north of the south quarter corner of sec. 1, at about the highest point stratigraphically on the anticline that has yet been drilled, a dry hole was obtained. This well did not penetrate the "Mississippi lime," however, and is therefore not a conclusive test. It is logical to assume that either oil or gas will be found in the crest of this fold.

The oil obtained has all come from the Bartlesville sand, though in some of the wells showings of oil are reported in the "Oswego" and Big limes. Gas is reported from the top of the Bartlesville sand, from

[1] Locations of wells not seen during the field work were taken from plats furnished by the Bureau of Mines and the Empire and Barnsdall oil companies.

the "Oswego" and Big limes, and from thin sands below the "Oswego lime" and above the Big lime.

The anticline has a large gathering ground to the north and west, but a relatively small one to the south and east, owing to the rather deep depressions in these directions.

PENCRESDALL ANTICLINE.

The Pencresdall anticline lies mainly north of Birch Creek in sec. 23 but occupies also the southwest corner of sec. 13, the SE. ¼ sec. 14, the northwest corner of sec. 24, and the north-central part of sec. 26. In outline it is somewhat pear-shaped, with the large end to the northeast. Its maximum extent from northeast to southwest is about 2 miles and its maximum width about 1 mile. The greater dips are to the north, west, south, and southeast and amount to about 50 feet within the first half mile. The drop to the east is less than 20 feet.

The northern part of this anticline has been developed by the Pen Mar, Crescent, and Barnsdall oil companies, and the extreme south end by the Barnsdall Oil Co. and the Prairie Oil & Gas Co. (See Pl. V.) The oil and gas thus far obtained come from the Bartlesville sand, though traces of both oil and gas are found at higher horizons. The initial production of the wells ranged from 5 to 700 barrels a day, but only three of them exceeded 200 barrels. As may be seen from Plate V, most of the wells are on the sides of the anticline. Two wells in the northwest corner of sec. 23, on top of the anticline, obtained about 1,000,000 cubic feet of gas a day from the Bartlesville sand but no oil. This suggests that gas rather than oil may be found in the top of the anticline. If future development should prove this to be the condition, drilling should be continued well down into the "Mississippi lime" in order to determine whether or not an adequate commercial supply of gas or possibly of oil may be obtained. The wells referred to above apparently did not penetrate the "Mississippi lime." Dry holes have been obtained well down toward the base of the fold in several places, indicating that oil will probably not be found in the adjacent synclines.

SOUTH COCHAHEE DOME.

The South Cochahee dome includes the SE. ¼ sec. 4, nearly all of sec. 5, the southeast corner of sec. 6, and the northeast corner of sec. 7. In sec. 6 it connects by a narrow saddle with the North Cochahee dome, lying to the northeast, mainly in T. 25 N., R. 10 E. The South Cochahee dome is somewhat oblong, having an east-west length of about 1½ miles and a north-south width of nearly 1 mile. The highest point of the dome lies about 800 feet north-northwest of the south quarter corner of sec. 5. The eastward dip is very gentle, amounting to less than

20 feet in about three-quarters of a mile. The north and south slopes are also gentle, that to the north being somewhat the steeper. The slope to the west is relatively steep, amounting to 60 feet in about half a mile. It is probable from the present development that the low saddle which connects this dome with the North Cochahee dome will prove to be productive oil or gas territory.

This dome is practically undeveloped. A well drilled in the southwest corner of the NE. ¼ sec. 6 (see Pl. V) had an initial production of about 50 barrels. A well a few hundred feet west of this one, drilled since the mapping was completed, is reported to have been brought in with an initial production of about 500 barrels. Another well about the same distance south of the one shown on the map is said to have come in with a production of about 50 barrels. The oil probably comes from the Bartlesville sand, though no complete log is yet available.

The existing developments indicate that the crest of this fold, like that of the North Cochahee dome, will probably yield gas and that oil will be found on the slopes. The dome has a fairly good gathering ground.

NORTH COCHAHEE DOME.

The North Cochahee dome lies mainly in T. 25 N., R. 10 E., and will be described in the report on that township. A few gas wells have been obtained on that part of the dome lying in this township. A log of one of these wells, showing the quantity of gas and the horizons at which it was obtained, is given in column 2, Plate VI.

EAST BIRDSEYE ANTICLINE.

The East Birdseye anticline occupies the SW. ¼ sec. 18 and the NW. ¼ sec. 19, with a narrow southeastward-projecting nose extending diagonally across the NE. ¼ sec. 19. It is separated from the main Birdseye anticline, to the west, by a low saddle. The highest point on the anticline seems to lie about on the line between secs. 18 and 19, at a point about 1,800 feet from the west side of the township. This small fold has an east closure of about 25 feet over an area of about half a square mile. It has not been developed, but conditions will probably be about the same here as in the main Birdseye anticline in T. 24 N., R. 9 E., except that this anticline is probably somewhat less favorably situated for oil and gas than the one to the west, because that one would trap the oil migrating up the westward slope. There is, however, considerable gathering ground to the north and south from which oil and gas might have been accumulated. It seems, therefore, that the East Birdseye anticline is well worth testing.

FOURMILE DOME.

The main part of the Fourmile dome lies in T. 24 N., R. 9 E., and is more fully described in the report on that township. The part of the dome lying in this township occupies the SW. ¼ sec. 30. The dome is somewhat larger from east to west than from north to south and occupies less than 1 square mile. It has an east closure of about 30 feet, and its crest is about 1,500 feet west and a little north of the southwest corner of sec. 30. The developments on that part of the anticline lying in this township are mainly on its north slope, where seven wells have been drilled. Each of these wells obtained oil in the Bartlesville sand, and their initial daily production ranged from 5 to 75 barrels. A dry hole was obtained on the east slope of the fold near the south quarter corner of sec. 30, limiting the probable productive area in this township to the SW. ¼ sec. 30. The dome has a large gathering ground to the north, south, and west.

TERRACES.

In the N. ½ sec. 22 the Massachusetts-Oklahoma (formerly Pen Mar) Oil Co. has several productive oil wells on what seems to be a terrace having a belt of steep dips about half a mile wide with a flat or terrace both above and below. The production is obtained chiefly in the zone of steep dips and at the inner edge of the lower terrace. Dry holes have been obtained on the flat above the steep dips, and also in a small synclinal reentrant north of the main producing area. The wells are small, the initial production after shooting ranging from 5 to 75 barrels. At present they yield only a few barrels each per day. The oil comes from a shallow sand 125 to 150 feet above the Big lime and about 650 feet above the Bartlesville sand. A log of one of these walls is shown in column 3, Plate VI.

The occurrence of oil at this place, away from any anticline or dome, may be the result of the terrace structure or it may be due to a lenticular sand or some other unknown factor. It simply illustrates the possibility of finding small pools of oil independent of anticlines or domes.

Terraces very similar to that in sec. 22 occur in the W. ½ sec. 3 and the W. ½ sec. 25. The terrace in sec. 3 is more pronounced structurally than that in sec. 22, being characterized by broader flats both above and below the belt of steep dips. However, notwithstanding this more favorable structural condition, the chances for oil accumulation are probably less in sec. 3 than in sec. 22, because the South Cochahee dome, immediately west of sec. 3, would trap the oil that otherwise might have migrated up the slope from the west.

The terrace in sec. 35 has a broad upper flat in which three dry holes have already been drilled. The lower flat is less well marked but may be sufficient to have produced the same effect as that in sec. 22, providing there was an available source of oil. It should be recognized, however, that the chances for obtaining oil in these terraces is considerably less than in well-defined anticlines or domes.

SYNCLINES.

In secs. 12 and 13 there is a deep syncline which, in view of the number of dry holes obtained around its margin, is exceedingly unpromising oil and gas territory. A similar syncline occurs in the NW. ¼ sec. 25 and extends southward across sec. 26. Other synclines in which oil will probably not be obtained occur in parts of secs. 17, 18, and 19.

T. 25 N., R. 9 E.

By K. C. Heald.

INTRODUCTION.

The field work in T. 25 N., R. 9 E. (see fig. 1), on which the accompanying report is based, was done by K. C. Heald, K. F. Mather, D. E. Winchester, D. D. Condit, F. R. Clark, and W. B. Emery, geologists, assisted by J. Lee Bossemeyer, W. G. Gulley, Willard Miller, J. M. Vetter, H. J. Weeth, Lewis Mosburg, and Richard L. Triplett, instrument men. The areas mapped by the different men interfinger so intricately that it is not practicable to outline the portion worked by each man. The names of the geologists are given in the order of their responsibility for the completed map.

KEY BEDS.

The exposed rocks in this township are all of upper Pennsylvanian age and include sandstone, limestone, and shale. Sandstones predominate, forming more than half of the total thickness of the exposed rocks, but there are some thick beds of shale, and in the western part of the township limestones are very conspicuous. (See Pl. VII and fig. 6.)

The geologic structure was determined from elevations taken on a great number of beds. Some of these beds occur only in very small areas, but others are traceable for long distances. The more persistent and helpful of these key beds are described briefly below.

Oread limestone.—The middle bed of the Oread limestone of Kansas is unquestionably one of the most important key beds in the Pawhuska quadrangle. It immediately underlies the Elgin sandstone and is particularly helpful in deciphering the structure because there are no other persistent limestones, either above or below it within 100 feet.

The character of this bed is not constant. In the NE. ¼ sec. 15, where it is well exposed in a gully on a steep hillside, it is about 3 feet thick; creamy brown on the weathered surface and a little darker on the fresh surface, with many dark-brown blotches; hard

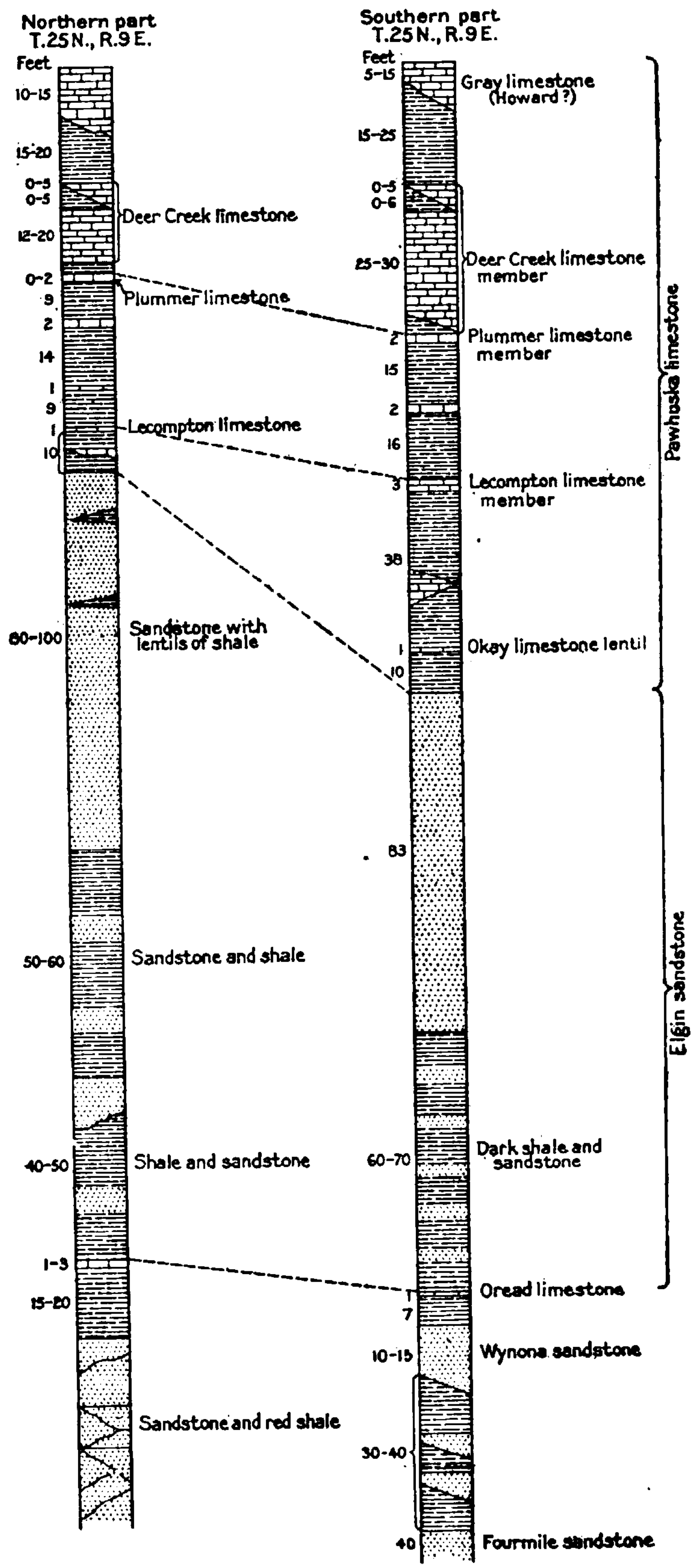


FIGURE 6.—Stratigraphic sections showing rocks exposed in T. 25 N., R. 9 E.

but not massive, breaking down into little slabby chips; and fossiliferous. It is overlain and underlain by thin beds of dark olive-drab shale which is almost as good a marker as the limestone itself, as the color is quite characteristic and it is in places very fossiliferous, differing in this respect from most of the shales in this part of the stratigraphic section. The olive-drab shale above the limestone is succeeded by fissile gray shale. That below is underlain by red shale.

Near the southern edge of the township this limestone, where well exposed, forms a single massive ledge of very hard rock, orange-red on the weathered surface and lighter on the fresh surface which is characterized by much milky calcite. Though this ledge is well exposed at only one or two localities the horizon may be traced by a string of limestone nubbins, ranging in size from that of a pinhead to 3 inches in diameter, which mark the location of the bed. There are other horizons where these limy concretions occur, but this particular formation can be identified by the fossils that weather out of the limestone or the associated shales. *Ambocoelia planiconvexa* and *Worthenia tabulata* are among the most common forms.

Okay limestone.—The Okay is a thin limestone, named from its good exposures on and in the neighborhood of the O. K. ranch in sec. 31. It is the lowest limestone in the Pawhuska formation, its stratigraphic position being about 10 feet above the highest bed of the Elgin sandstone and 50 to 100 feet below the Deer Creek member of the Pawhuska limestone. The color ranges from gray to buff, but the buff predominates. In most places the rock is of flinty hardness and contains an abundance of small *Fusulina*, but either or both of these features may be locally absent.

This limestone appears to be a rather small lentil. It does not crop out north of Clear Creek in this township, and although it extends to the southern line of T. 24 N., it has not been noted by the geologists working the territory to the south.

The outcrop of the bed is inconspicuous, and in places it is traced with extreme difficulty, but such good outcrops as occur are easily found because of their stratigraphic position with respect to the underlying massive Elgin sandstone.

Lecompton limestone.—The Lecompton limestone is a member of the Pawhuska formation, lying 10 to 40 feet above the Elgin sandstone and 30 to 60 feet below the Deer Creek limestone, which is the Pawhuska limestone of the commercial geologists. It is one of the most persistent of the members of the Pawhuska formation and has been traced from the Kansas line through the Pawhuska quadrangle, through the Hominy quadrangle, where it is known to some as the "Hominy lime," and south to the Cushing field, where it is known as the "Pawhuska lime."

It is a hard bed, is not more than 3 feet thick in this township, although much thicker in the region to the south, and forms a conspicuous outcrop in many places, large slabs of it breaking off and littering the hill slopes. Its resistance to disintegration may lead to mistakes in mapping, as large slabs of it that show little or no effect of weathering occur on slopes or in stream beds far below the actual outcrop. The weathered color is commonly orange, though locally it is gray. The fresh surface is lighter in color. The limestone is not markedly fossiliferous except in small areas, but almost anywhere a search will reveal small cup corals (*Lophophyllum profundum*). It is well exposed in sec. 31 near the O. K. barn.

Deer Creek limestone.—The Deer Creek limestone is the most conspicuous member of the Pawhuska formation and is the bed to which the name Pawhuska was originally applied. It ranges in thickness from 12 to 41 feet in this township. The general color of the weathered surface is gray, but there are bands which are cinnamon-brown and blackish blue. These bands are so persistent that they can be traced for considerable distances and used in mapping to determine the structure. In this township a brown band near the top of the limestone and the very top part of the bed, which is of a very dark blackish-blue color with a peculiar velvety-smooth appearance, were especially helpful in mapping.

The Deer Creek limestone is present along the western margin of the township as far south as the south line of sec. 30. Care should be exercised in using it for mapping structure, as there is a pronounced divergence southward between it and the Lecompton limestone, and a still more marked one between it and the top of the Elgin sandstone. (See stratigraphic section, fig. 6.)

PENNSYLVANIAN ROCKS BELOW THE SURFACE.

The unexposed rocks above the Mississippian limestone are of the same general type as those which appear on the surface. (See fig. 7.) Sandstone and shale make about 90 per cent of the total above what is known to the drillers as the Big lime (probably the Pawnee limestone of the Kansas section). Below that horizon there is comparatively little sandstone, but there are massive beds of limestone and much shale. Many of the sandstones in the upper part of the section are water bearing, even on pronounced anticlines, and in some of the synclines they yield great quantities of either salt or fresh water. Most of these water-bearing sands are apparently lenticular, so that wells some miles apart will not always get the water at the same horizons. Two of the sands, however, appear to be present wherever wells have been drilled in the township. The top of one of these sands is commonly found from 160 to 230 feet below the middle bed

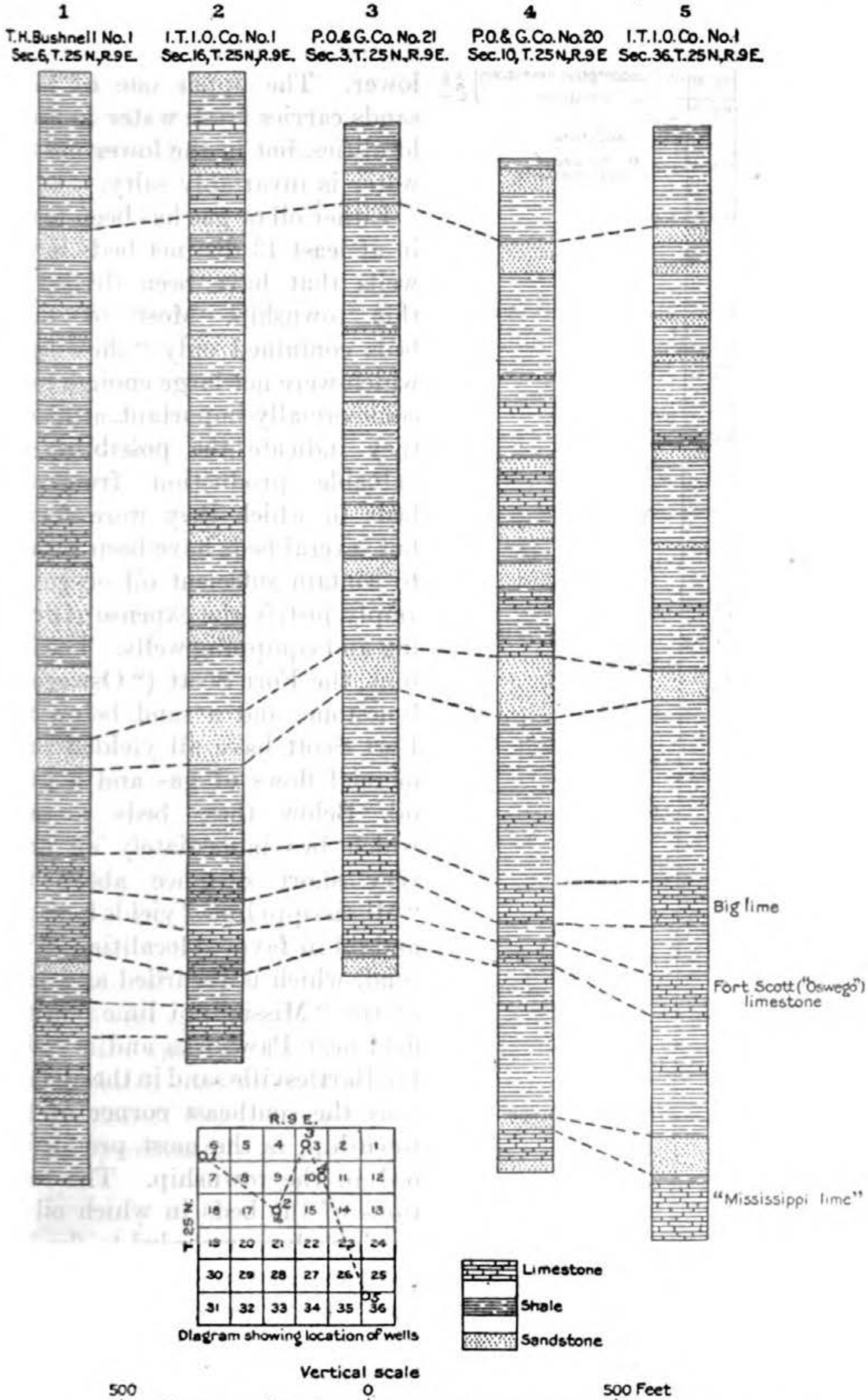


FIGURE 7.—Sections of rocks underlying T. 25 N., R. 9 E., as shown by well records.

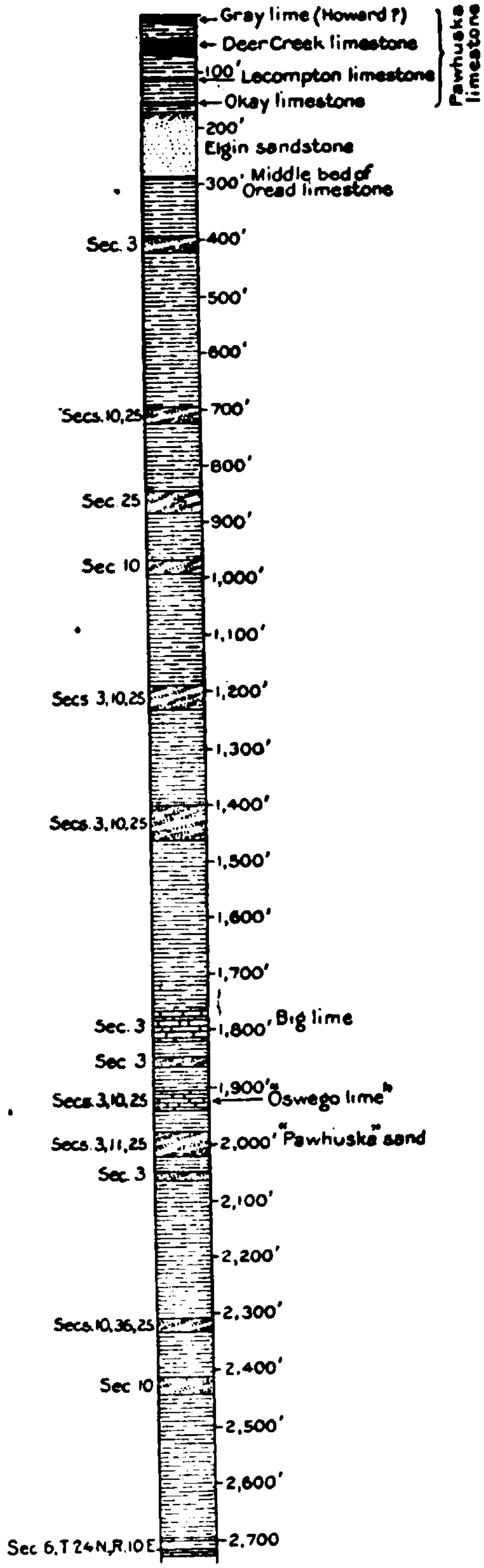


FIGURE 8.—Composite section showing relation of exposed rocks to beds carrying either oil or gas in T. 25 N., R. 9 E.

of the Oread limestone, and the top of the other about 1,000 feet lower. The upper one of these sands carries fresh water in many localities, but in the lower one the water is invariably salty.

Either oil or gas has been found in at least 13 distinct beds in the wells that have been drilled in this township. Most of these beds contained only "showings," which were not large enough to be commercially important, although they indicate the possibility of valuable production from the beds in which they were found, but several beds have been proved to contain sufficient oil or gas to amply justify the expense of drilling and equipping wells. The Big lime, the Fort Scott ("Oswego") limestone, and a sand below the Fort Scott have all yielded commercial flows of gas and a little oil. Below these beds a sand which lies immediately on or a very short distance above the "Mississippi lime" yields both gas and oil in favored localities. This sand, which is regarded as a part of the "Mississippi lime" in the field near Pawhuska and is called the Bartlesville sand in the oil field near the southeast corner of the township, is the most productive bed in the township. The relations of the beds in which oil or gas have been recorded to the key beds exposed on the surface is shown by figure 8.

Besides the oil and gas bearing beds mentioned above, there are unquestionably deeper sands 200 feet or more below any which have been reached by drilling operations in T. 25 N., R. 9 E. The higher of these deep-lying sands have been proved to contain both oil and gas in other parts of the Osage Reservation, and it seems practically certain that future deep drilling in this township will result in the development of good yields from one or more of these lower beds.

STRUCTURE.

GENERAL FEATURES.

The structure in T. 25 N., R. 9 E., is complicated. Viewed broadly the beds dip a little north of west, but this regional tendency is so

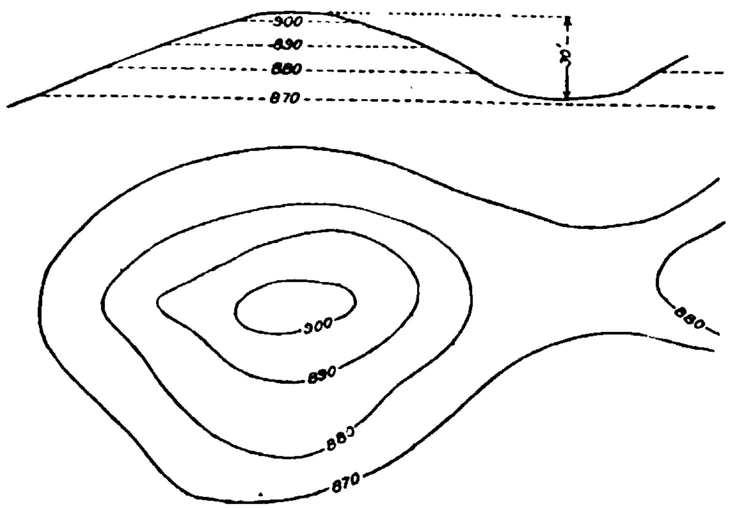


FIGURE 9.—Sketch illustrating an anticline with a closure of about 30 feet.

obscured by the manner in which the beds are folded and faulted that it is not in the least prominent.

The term "closure," which is used in the following descriptions of the individual anticlines, may for all practical purposes be taken to mean the vertical distance between the highest and lowest closed contours on the anticline plus the contour interval. For example, if the highest closed contour represents an elevation of 900 feet, the lowest an elevation of 880 feet, and the contour interval is 10 feet, the closure is approximately 30 feet. (See fig. 9.)

LOOKOUT ANTICLINE.

The highest point of the Lookout anticline lies near the northeast corner of T. 25 N., R. 9 E., and the fold outlined by the closed contours covers territory in all four of the townships that corner here. (See fig. 10.) The dips on all sides are sufficiently pronounced to be detected without difficulty, and the closure is about 40 feet. The area in which the structure seems favorable for the accumulation of oil is about 2 square miles. This includes a projection or anticlinal nose which extends through the center of sec. 1 and covers much of the S. ½ of sec. 2.

Two wells have been drilled on this anticline since the completion of the field work on which this report is based. One, in sec. 36, T. 26 N., R. 9 E., obtained a large volume of gas in several of the shallower gas-bearing zones and a very strong flow from the Fort Scott ("Oswego") limestone. A second well, in the SW. ¼ sec. 31, T. 26 N., R. 10 E., was drilled through the horizons of the gas-bearing beds of the well in sec. 36 and obtained oil in commercial quantity from the "Mississippi lime." This was to be expected, as on another anticline in sec. 35, T. 26 N., R. 9 E., less than 2 miles distant, wells ranging in initial production from 25 to 150 barrels a day produce from this oil-bearing zone, and it also yields oil in sec. 10, T. 25 N., R. 9 E., 3 miles to the southwest.

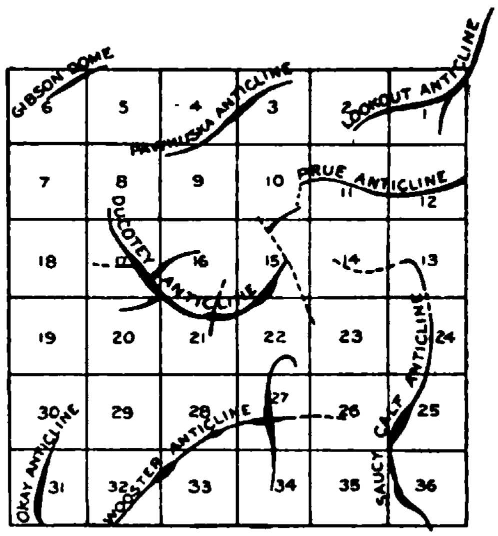


FIGURE 10.—Sketch showing approximate positions of the axes of anticlinal folds in T. 25 N., R. 9 E.

To judge from the general shape and size of this anticline and from the area of the gathering ground from which oil may have migrated to accumulate under the anticline, it does not appear probable that any large yields will be obtained here. However, it does seem practically certain that a large part of the acreage covered by the anticline will yield gas from the shallower sands and oil and gas from the deeper ones. There is also a possibility of oil from the Big lime, the "Oswego lime," or some other of the beds that have yielded showings of oil near by, as well as from beds 100 feet or more below the top of the "Mississippi lime."

PAWHUSKA ANTICLINE.

The Pawhuska anticline, which is crowned by a domelike bulge, covers the W. ½ sec. 3 and the E. ½ sec. 4. The total area covered by beds that are distinctly arched is a little less than a square mile, but the tendency of the structure to influence the accumulation of oil and gas may extend over a considerably larger area. The highest part of the fold is in the SE. ¼ NW. ¼ sec. 3, around which there is a closure of 30 feet.

This anticline has already been extensively drilled. There are several gas wells on its crest and east flank, and the gas field extends across the synclines to the south and east and yields gas from beds low on the flanks of the Prue anticline and the Lookout anticline.

According to the records now available the wells have come in with initial yields as high as 22,000,000 cubic feet a day, but estimates on the flows of some of the first wells brought in place the initial production as high as 40,000,000 cubic feet. Gas was encountered in a number of sands above the Fort Scott ("Oswego") limestone, but the principal producing bed is a sand a little below the Fort Scott. This sand gave good showings of oil in several of the wells, but never enough to make oil production practicable. Two of the wells, in the southeast corner of sec. 3, were drilled to the "Mississippi lime" without encountering additional oil-bearing zones. However, neither of these wells is very favorably located with respect to the structure. One of them is reported to have penetrated the lime to a depth of almost 100 feet, which would insure its passing through the oil-bearing beds of the wells to the northeast and the south, but it can not be said that an adequate test of the oil-bearing possibilities of the "Mississippi lime" under this fold has been made.

The west flanks of most anticlines in the Osage country are far more likely to be productive than are the east flanks. If this holds true for the Pawhuska anticline the most favorable territory on that fold is still undrilled. The only well sunk on the west flank is in the northeast corner of sec. 8 and is so far down the dip that it lies in the trough of a syncline and hence is most unfavorably located. No oil or gas was found in it. It seems quite probable that when the portion of the anticline lying in the E. ½ and NW. ¼ sec. 4 is drilled not only will productive gas wells be obtained, but commercial quantities of oil may also be encountered in the sand which lies close beneath the Fort Scott ("Oswego") limestone, in the upper part of the "Mississippi lime," or in some bed which lies more than 100 feet below the top of the lime and has not yet been reached by the drilling in this general region. A good location for a test is in the town site of Pawhuska near the center of the SE. ¼ sec. 4. This locality may have been drained of a part of its content of gas by the old wells to the northeast, but the deeper sands that were not touched by those wells should be productive. If the well is located on top of the hill the Big lime should be struck at a depth of about 1,500 feet, the "Oswego" at about 1,650 feet, and the "Mississippi" at about 2,050 feet. The drilling should be carried to a depth of 2,400 feet unless oil is encountered at shallower depth. A second location for a test is about 2,600 feet east of the west line and 1,300 feet south of the north line of sec. 4. A third good location is a little east of the center of the SE. ¼ SW. ¼ sec. 4.

GIBSON DOME.

The Gibson dome is a small anticlinal bulge that lies mainly in the northwest corner of sec. 5 and the northeast corner of sec. 6, T. 25 N., R. 9 E., and extends into the southeast corner of sec. 31, T. 26 N.,

R. 9 E. The crown of the dome lies across the line between secs. 5 and 6. The closure is about 20 feet. The area included within the lowest closed contour is little more than a quarter of a mile, and it appears doubtful if the fold is pronounced enough to influence the accumulation of oil or gas over an area of more than half a section.

The eastern flank of this dome is cut by small faults that have a maximum throw of about 25 feet. This displacement is so small and the lateral extent of the breaks is so slight that it does not appear probable that they will affect in any way the oil-retaining possibilities of the fold, but if they do the modification is of such a nature as to make the oil or gas reservoir more effective than it would be if the faults were absent.

This dome has never been drilled. A test which was made in the extreme southwest corner of sec. 6, a mile from the crown of the fold, was carried to the "Mississippi lime" without obtaining either oil or gas in commercial quantity. In fact, the record of this test does not mention even showings of oil or gas.

Conditions are favorable, so that drilling is amply justified. A good location is near the center of the NE. ¼ sec. 6. An alternative location is the extreme northeast corner of sec. 6. If the well is located on the limestone capping the hill, the "Oswego lime" should be struck at a depth between 1,850 and 1,900 feet and the "Mississippi lime" between 2,300 and 2,400 feet.

DUCOTEY ANTICLINE.

The Ducotey anticline is a large fold of irregular shape, whose axis trends in a curved line from the SW. ¼ sec. 17 to a point a little north of the quarter corner between secs. 10 and 15, where it is lost in a long, flat saddle. The general outline of the axis is that of a crescent with the tips pointing northwest and northeast. (See fig. 10.)

There are four distinct domelike humps separated by short saddles on the axis of this anticline, and its flanks are indented by many minor marginal synclines of irregular size and outline. It is, however, definitely bounded on the north by the axis of a major syncline that follows very closely the bed of Bird Creek, on the west and northwest by a monocline that dips west across Clear Creek from a line about a mile east of the creek bed, on the south by a synclinal depression that crosses the southern parts of secs. 20, 21, and 22, and on the east by flat-lying beds that limit it near the east line of sec. 15. The four highest points on this anticline are in the SE. ¼ sec. 17, the NW. ¼ NE. ¼ sec. 21, the SE. ¼ SW. ¼ sec. 15, and the NE. ¼ NW. ¼ sec. 15.

Several faults break the surface beds on this anticline, and three of them are so large that probably they also affect the rocks at the depth of the oil and gas-bearing beds. One of these faults trends northwestward across the extreme northeast corner of sec. 20 and the SE. ¼ sec. 17 and has a downthrow to the southwest of 25 feet in maximum amount. A second trends north-northwestward across the west side of sec. 16. The downthrow on this fault is to the northeast and is a little more than 20 feet at the point of maximum displacement. The third large fault crosses sec. 15 near the middle of the section. The maximum displacement along this fault is in the southeast corner of the section, where the beds are dropped about 45 feet to the northeast.

Several wells have been drilled on the flanks of this anticline, but with a single exception they are so far down toward the bordering synclines that their failure to obtain either gas or oil in paying quantity is fully explained. The single exception is a test which was drilled in the NE. ¼ NW. ¼ sec. 15, squarely on the crown of the easternmost of the humps which cap the axis of the anticline. It is reported that this well was carried deep enough to penetrate the "Mississippi lime" for at least 50 feet without encountering commercial amounts of either oil or gas, although there were showings of both. A fault passes immediately west of the well and may reach the oil-bearing sand with a displacement sufficient to seal it effectually so that little or no oil or gas could get to the vicinity of the well. However, it is much more likely that the failure of this well is due to local sand conditions, or to the fact that the structure in depth does not parallel that on the surface.

The Ducotey anticline is worthy of very complete testing. Good locations are the NE. ¼ SW. ¼ sec. 15, about the center of sec. 17, the center of the NE. ¼ NE. ¼ sec. 20, and the NW. ¼ NE. ¼ sec. 21.

PRUE ANTICLINE.

The Prue anticline is a long, relatively narrow fold whose axis trends approximately east near the middle of secs. 11 and 12. The area encircled by the lowest closed contour on this fold is only about a square mile, in spite of its length of more than 2 miles, and the closure of 10 feet is insignificant. On the west a saddle separates this anticline from the Ducotey anticline. On the east the outline of the fold is lost under the alluvium of the Bird Creek valley. On the north the rocks dip steeply toward the axis of the syncline that separates this fold from the Pawhuska anticline.

Three faults cut the Prue anticline, but none of them is large enough to have any appreciable effect on the accumulation of oil or gas unless it is a good deal more pronounced in depth than it is on the surface.

Some successful drilling has been done on this anticline. Two wells located very close to the axis in sec. 10 had initial yields of

20 and 25 barrels from the "Mississippi lime." An offset to one of these wells did not make enough oil to be put on the pump but was shut in as a gasser. Two other wells drilled near by had showings of both oil and gas but not enough to make them of value. Besides these wells five others have been bored on the southern flank of the fold. One of them, in the south-central part of sec. 11, was favorably located with respect to the structure, but although it showed some gas there was not enough to justify maintaining it, and it was abandoned.

Though this anticline does not appear to promise large wells, a considerable number of wells of moderate productivity will probably be drilled on it ultimately. Gas may be hoped for at any one of five horizons, ranging from 900 feet above the "Oswego lime" to about 100 feet below the top of the "Mississippi lime," and oil may be looked for either in the bed immediately overlying the "Mississippi lime" or in a bed at greater depth.

Good locations for testing are 500 feet south of the center of the NW. ¼ sec. 11 and about 1,300 feet west of the east quarter corner of sec. 12. These tests should be carried to a depth of at least 2,300 feet if they are to be adequate.

OKAY ANTICLINE.

The axis of the Okay upfold trends from north to south near the center of sec. 31. (See fig. 10.) The anticline is not particularly prominent, for though the dips to the north and west are pronounced, those to the east and south are both gentle and small in vertical extent. The slightest dip is to the south, where the highest point of the saddle that limits the fold on the south is only about 20 feet below the highest point on the anticline.

The possibilities of this anticline are hard to forecast. No drilling has been done within several miles, so the position and character of the possible oil sands here can only be guessed. To judge from the conditions found in the nearest wells there will probably be little or no sand at the horizon generally ascribed to the Bartlesville sand, a short distance above the "Mississippi lime." Accordingly oil must be looked for either in higher beds, particularly in the Fort Scott ("Oswego") limestone and the sand a little below the Fort Scott, from which the heaviest flow of gas in the Pawhuska field is obtained, or in beds associated with the "Mississippi lime," particularly one just capping the lime and a second 90 to 120 feet lower. Drilling 6 miles to the east has indicated that a third possibly productive bed may be expected still deeper in the lime.

A good location for a test appears to be the center of sec. 31. A well located here should strike the Fort Scott limestone between 1,750 and 1,800 feet below the surface, and the "Mississippi lime" between

2,100 and 2,200 feet. A second location is the northeast corner of the NW. ¼ sec. 31. The beds mentioned above will be found to lie a little farther below the surface here than in the center of the section.

WOOSTER ANTICLINE.

The Wooster anticline is a pronounced fold of very irregular outline. The main axis runs in a curving line from the center of the south line of sec. 32 to the center of the east line of sec. 27. Near the middle of sec. 27 this main axis is cut by that of a minor transverse fold which extends north into sec. 22 and south into sec. 34. The branch that runs into sec. 34 is further modified by a small domelike fold to the west of the axis of the larger anticline. The uplift as a whole might be described as an anticline capped by four domes, as there are four domelike dwellings strung along the axis of the major fold and definitely separated by structural saddles.

The territory covered by the distinctly anticlinal structure—that is, by beds which are unquestionably arched—is about 3 square miles in secs. 27, 28, 32, 33, and 34. Not all this area will necessarily yield oil or gas, nor will the production of oil or gas necessarily stop within the limits of the sections mentioned. However, the structure in the territory mentioned is unquestionably of a nature to induce the accumulation of oil or gas, and it is to be hoped that at least a large part of this territory will ultimately prove productive. If this hope is realized it also seems fair to expect that the producing sands will be found to extend westward beyond the limits given above, as the general experience in the Osage country is that oil is found much farther down on the west flanks of anticlines than it is on the north, east, or south flanks.

The proximity of this anticline to the producing wells in secs. 25, 26, 35, and 36 leads to the hope that conditions similar to those in the producing wells will be found under the Wooster anticline. If so, the oil will probably come from the sand known locally as the Bartlesville, which lies just above the "Mississippi lime," although there are also chances of production from shallower sands, notably one 300 feet and another 900 feet above the Bartlesville (?) sand. The depth at which the sands will be encountered will depend on the topography, but in no well drilled on this fold should the Bartlesville (?) lie more than 2,200 feet below the surface.

There appears to be a strong possibility that oil sands lying from 100 to 300 feet below the Bartlesville (?) may be present, and at least one well-located test should be carried to a depth sufficient to prove the character of these lower beds.

Good locations for testing are indicated by the structure to be the southeast corner of the NE. ¼ NE. ¼ sec. 32, the southwest corner of the NW. ¼ SE. ¼ sec. 28, the center of sec. 27, and the center of the SW. ¼ sec. 34.

SAUCY CALF ANTICLINE.

The curving axis of the Saucy Calf anticline trends northward through the western part of secs. 36 and 25 and terminates a little north of the center of sec. 24. (See fig. 10.) The structure is marked by pronounced dips on the north, west, and south, but the dip on the east is much more gentle. The closure is about 25 feet. The anticline is a moderately large one, as the lowest closed contour encircles an area of about 1½ square miles, and the area in which the rocks are flexed into an anticlinal arch is considerably greater.

A group of wells on the crest and east flank of this anticline obtain oil from the "Oswego lime" and Bartlesville (?) sand. Showings of oil and gas have been found in other sands, but not in sufficient quantity to justify their exploitation. The initial production from the Bartlesville sand ranged from 20 to 1,000 barrels a day; the "Oswego lime" yielded from 6 to 20 barrels a day. The condition of the sands beneath this anticline appears to be peculiar, for some of the biggest wells are far down the east flank, where structural conditions as shown by the surface rocks are not particularly favorable for oil accumulation, whereas the only two dry holes that have been drilled are excellently located with respect to the surface structure. For this reason it appears probable that the dry holes do not in any sense mark the borders of the field, but that drilling beyond them may result in further production.

The chances are excellent that a large area on this anticline will yield oil. The present field will probably be extended in every direction. The oil sand may even continue to yield under the shallow syncline that bounds this anticline on the east, although the percentage of oil to gas will grow less and less as the drilling is carried eastward until nothing but gas is obtained, this field being thus joined with the small gas field that has been opened in the extreme southeast corner of sec. 36 and in the sections lying immediately east and southeast of sec. 36.

A deep well that was drilled about a mile southeast of the oil field in sec. 36 proved the presence of a gas-bearing layer more than 200 feet below the lowest producing bed in this field, and it is highly important that wells be drilled deep enough on the Saucy Calf anticline to test this layer and the beds for some distance below it. This will involve drilling to a depth of 2,400 feet or more.

UNFAVORABLE AREAS.

When the structure of T. 25 N., R. 9 E., is considered in a general way it appears that a very large part of the township lies in a zone of marked deformation. This indicates weakness in the rocks or unusual deformational stresses in this restricted zone, or both. In any event it seems probable that the crumpling of the beds has been going on for a long period—probably since pre-Pennsylvanian time—and that the deep-lying beds accordingly have many wrinkles which do not appear on the surface. The general experience in the Osage region is that these zones of deformation are very likely to contain many pools of oil and gas which are to a certain extent independent of the minor structural features developed at the surface, and accordingly there are few localities in such a zone which are not worthy of a test by drilling. However, one or two districts in the township appear so distinctly unfavorable that it seems best to point them out. Among them is that part of the Bird Creek syncline which follows the course of Bird Creek from the east-central portion of sec. 5 to the center of the NE. ¼ sec. 9. No part of sec. 7 appears promising, and the W. ½ sec. 18, the N. ½ sec. 19, and the W. ½ sec. 20 fall in the same category. The broad, flat area which includes the S. ½ sec. 12, N. ½ sec. 13, and the N. ½ sec. 14 seems to be decidedly unfavorable. The syncline which covers the SE. ¼ sec. 34, and the W. ½ sec. 35 should be avoided, as should also the SE. ¼ sec. 33. Although it is not impossible that oil will be found in any of these unfavorable districts, it seems most likely that no commercial quantities will be obtained. At best they should be left undrilled until the remainder of the township has been explored, and even then they should not be drilled unless the conditions in some adjoining areas are so favorable as to indicate that they contain the extensions of some previously discovered pools.

T. 28 N., RS. 9 AND 10 E.; T. 29 N., R. 10 E.

By C. F. BOWEN.

STRATIGRAPHY.

EXPOSED ROCKS.

THICKNESS AND GENERAL CHARACTER.

The rocks exposed in T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E. (see fig. 1), are illustrated graphically in figure 11. They have an aggregate thickness of about 650 feet and are of upper Pennsylvanian age. Above the Elgin sandstone there are numerous beds of limestone and some of sandstone interstratified with shale. Below the Elgin sandstone the rocks exposed consist mainly of sandstone and shale with only a few beds of limestone. In T. 28 N., R. 9 E., that part of the section above the base of the Wynona sandstone is exposed. In the other two townships the Elgin sandstone is the highest exposed formation. A detailed discussion of the stratigraphy and the grouping of formations will be given in the final report on the Pawhuska quadrangle. The present discussion is confined to the principal key beds used in mapping.

KEY BEDS.

The key beds of most value in working out the structure in this area are, in ascending order, the lower *Fusulina*-bearing limestone, the Labadie limestone, the middle bed of the Oread limestone, and the Lecompton, Plummer, Deer Creek, *Cryptozoon*-bearing, and upper *Fusulina*-bearing limestone members of the Pawhuska limestone. The outcrops of the lower *Fusulina*-bearing limestone, the Labadie limestone, the middle bed of the Oread limestone, and the Deer Creek limestone are shown on the map (Pl. VIII).

Other beds that may be used locally in studying the structure are a bed of ledge-making sandstone about the middle of the Elgin sandstone, the Wynona sandstone, and the two thin limestones below it, several sandstones between the Wynona sandstone and the Labadie limestone, and the top part of the sandstone between the Labadie limestone and the lower *Fusulina*-bearing limestone.

Lower Fusulina-bearing limestone.—The lower *Fusulina*-bearing limestone is a thin-bedded limestone 2 to 4 feet thick, containing an

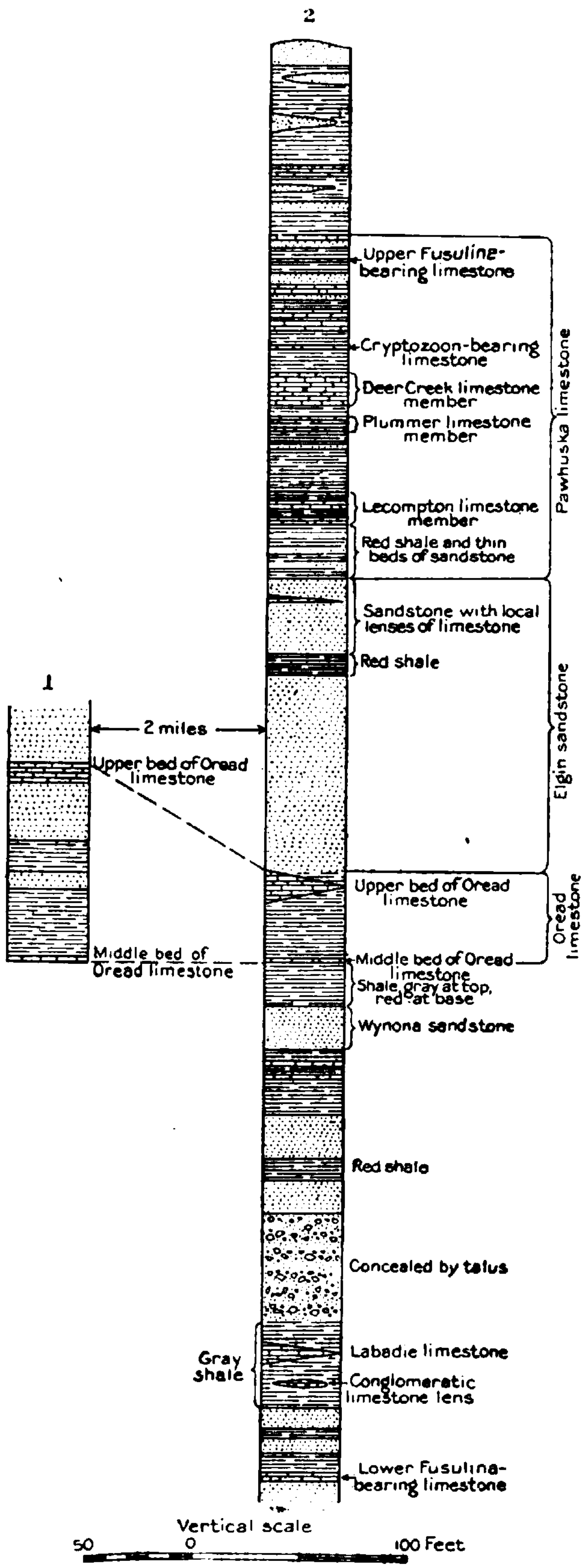


FIGURE 11.—Columnar sections of rocks exposed in T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E. (See p. 45.)

abundance of long slender Fusulinas, which in places constitute most of the rock. In many places its weathered surface has a slightly reddish tinge that is apparently due to infiltration from the red shale immediately above it. Locally it becomes more or less sandy or grades into calcareous sandstone. In most places it rests directly on a thick bed of sandstone, whose outcrop is marked by a line of trees. Above the limestone there is commonly a thin bed of reddish shale, overlain by about 20 feet of sandstone with some interbedded shale. The outcrop of the limestone is not conspicuous and can not be seen from a distance. After its relation to the sandstones above and below it has been learned, it can usually be found by careful searching, even in places where it does not crop out continuously. It is exposed chiefly along the margins of the valleys of Pond Creek and Caney River and is well exhibited in the dugway of the wagon road near the top of the hill on the south side of Pond Creek near the southeast corner of sec. 2, T. 28 N., R. 10 E.

Labadie limestone.—The Labadie limestone is about 175 feet below the middle bed of the Oread limestone and 65 feet above the lower *Fusulina*-bearing limestone. It is 8 to 10 feet thick on the point south of Mission Creek in the NE. ¼ sec. 36, T. 28 N., R. 10 E., but a mile north of that place it is not more than 3 or 4 feet thick. Where best developed the Labadie is a crystalline limestone with a steel-gray color on the fresh surface; on the weathered surface the upper part is brownish and the lower part gray. It is not prolifically fossiliferous but contains some small, plump, rounded brachiopods. As shown on the map (Pl. VIII), this limestone crops out only in the southeast corner of T. 28 N., R. 10 E. Toward the north it thins so rapidly that it can not be recognized north of the east quarter corner of sec. 24, but a limestone about 2 inches thick at about the same horizon as the Labadie was seen at several places farther north in Tps. 28 and 29 N., R. 10 E.

Oread limestone.—In this area the Oread limestone is represented by the upper and middle limestones of the Oread of Kansas, the lower limestone of the Kansas section not being present. The middle limestone of the Oread is one of the best key beds in the area here described. It is a dense, fine-grained limestone about 18 inches thick, that has a steel-blue color on the fresh surface and weathers to a dirty yellow. It breaks into wedge-shaped joint blocks and is sparingly fossiliferous; the most distinctive fossil is a small species of *Fusulina*. In some places this characteristic part of the bed is overlain by a small amount of fine lyconglomeratic limestone. The limestone is remarkably constant in thickness and lithologic character throughout the area and is so characteristic that it can not be mistaken after having once been seen. The outcrop of this bed is shown on Plate VIII.

The upper bed of the Oread limestone ranges from a few feet to 16 feet in thickness. It is a thin-bedded ledge-making gray limestone, and where best developed the upper part (about 7 feet) weathers brown and the remainder white. The lower part contains in places an abundance of two species of corals, *Campophyllum torquium* and *Syringopora multilineata*. The former is a single coral, the individuals of which may be as much as an inch in diameter and several inches long. The latter grows in colonies, some of which are 6 inches or more in diameter, and in longitudinal section exhibits a mass of long, slender tubes resembling organ pipes. In addition to the corals there is a species of *Fusulina* larger than that found in the middle bed. The interval between this bed and the middle bed of the Oread ranges from 25 feet at Artillery Mountain, in the SE. ¼ sec. 21, T. 29 N., R. 10 E. (see column 2, fig. 11), to 90 feet at Tinker Hill, in the SW. ¼ sec. 30 (see column 1, fig. 11). This increase in interval between the two limestones is taken up in part by an increase in the thickness of the shale between them but chiefly by the wedging in of sandstones that thicken to the south and west. As the sandstones thicken the upper bed of limestone thins somewhat and finally disappears rather abruptly between two beds of sandstone near the center of sec. 35, T. 29 N., R. 9 E. About 3 miles farther south, along the west side of Pond Creek, in secs. 14, 15, and 22, T. 28 N., R. 9 E., a lens of limestone, traceable for about 1 mile, having all the marks of the upper bed of the Oread and at about the same horizon, occurs between two beds of sandstone. The upper bed of the Oread has not been found south of Pond Creek.

Lecompton limestone.—The Lecompton limestone, the lowest limestone member of the Pawhuska limestone in this area, is about 190 feet above the middle bed of the Oread limestone and about 25 feet above the Elgin sandstone. The Lecompton consists of three beds of limestone separated by beds of shale, the whole about 12 feet thick. These limestones are gray and weather to a somewhat lighter color on the exposed surfaces, except that the upper part of the middle bed, and to some extent the lower bed, also weathers to a bright yellow. Fossils are abundant in some places and consist principally of large corals (*Campophyllum*) and ricelike *Fusulina*. This limestone generally crops out at the base of the slope above the Elgin sandstone and below the terrace formed by the Deer Creek limestone.

Plummer limestone.—The Plummer limestone member of the Pawhuska limestone consists of two thin beds, each about 1 foot thick, separated by about 5 feet of shale. The upper limestone, which makes the better key bed of the two, is about 35 feet above the top of the Lecompton limestone and consequently about 225 feet above the middle bed of the Oread limestone. The two beds of the Plummer are similar lithologically; the limestone is dense and fine-grained, has no apparent bedding planes, and is steel-gray to black on the fresh surface but slightly tinged with yellow on the weathered surface. It commonly crops out in the slope below the terrace formed by the Deer Creek limestone, from the base of which it is separated by about 5 feet of shale, and weathers out in large blocks which generally strew the slope. In places where the Deer Creek limestone has been eroded the upper bed of the Plummer may give rise to a more or less conspicuous terrace.

Deer Creek limestone.—The Deer Creek member of the Pawhuska limestone is 10 to 15 feet thick, and its upper surface is 15 to 20 feet above the Plummer limestone. The Deer Creek is a gray fossiliferous thin-bedded limestone, the lower part of which weathers white, is more resistant to erosion than the upper part, and commonly forms a rather prominent ledge bordering a broad sloping terrace, on the surface of which are many large white irregular slabs of the limestone. Above this white portion the limestone weathers gray with brown blotches, which are especially prominent in a bed near the top containing an abundance of large *Fusulina*. This *Fusulina*-bearing bed makes one of the best key beds in the Deer Creek limestone. On the whole, however, this limestone is too thick to constitute a good key rock, and more accurate results can be obtained by using the Plummer limestone below. The Deer Creek limestone is the most prominent member of the Pawhuska limestone, and its outcrop is therefore shown on Plate VIII.

Cryptozoon-bearing limestone.—About 12 feet above the Deer Creek limestone is a limestone about 1 foot thick, characterized by fossil Cryptozoa. This limestone is dense and fine grained and has a black color, which becomes dirty gray on the weathered surface. Because of the fossils that it contains it is readily distinguished from any other limestone in the area where it is exposed and is therefore a valuable bed on which to obtain elevations on the terrace above the Deer Creek limestone.

Upper Fusulina-bearing limestone.—About 35 feet above the *Cryptozoon*-bearing limestone and therefore about 47 feet above the top of the Deer Creek member is a gray limestone less than 6 inches thick that contains an abundance of small, slender *Fusulina*. It is about 9 feet below the topmost member of the Pawhuska limestone and is of value chiefly in establishing the identity of this upper member, which is commonly referred to as the "red lime" because of its rusty-red to brownish-gray color.

UNEXPOSED ROCKS.

General character.—The character of the rocks not exposed at the surface and their relation to those that are exposed are shown in columns 1–5, Plate IX. The best key bed of the unexposed rocks of this area is the "Oswego lime" of the drillers (Fort Scott limestone). It ranges from 50 to 100 feet in thickness and it is broken into three members by two thin beds of black shale generally about 5 feet thick. (See column 3, Pl. IX.) These shales are reported in so many well logs that they seem to be constant and would probably be recognized by all drillers who made careful observations. From 250 to 350 feet below the base of the "Oswego" is the top of the "Mississippi lime." About 100 to 150 feet above the top of the "Oswego lime" is a limestone commonly called the Big lime. This is not so good a key bed as either the "Oswego lime" or the "Mississippi lime." In some parts of the area where drilling has been done the Big lime seems to consist of a single bed 50 to 100 feet thick; in other places there are two beds of limestone each 40 to 50 feet thick separated by about 50 feet of shale. Some drillers refer to these beds as the Big lime and second Big lime. In still other places there seem to be several beds of thin limestone between the horizon of the top of the Big lime and the "Oswego lime." An bed that seems to be rather constant throughout the area is a t water-bearing sandstone (No. 4 of column 6, Pl. IX), which monly contains some gas in its upper part. The top of this sands is approximately 700 feet above the "Oswego lime." The o unexposed rocks are sandstones, shales, and thin limestones ha no distinctive characteristics.

Oil and gas bearing beds.—The beds in which oil and gas h been encountered in drilling are shown in column 6 of Plate They include the Big lime, the "Oswego lime," and the "Mississi lime"; two or three thin sands between the "Oswego lime" and "Mississippi lime"; at least two sands between the "Oswego" a Big limes, either of which is called the Peru sand by the drillers; a several thin sands above the water-bearing sand described abo The Bartlesville sand is not generally recognized in this area. may be represented in part by a thin sand that lies just above t the "Mississippi lime," and is referred to as the Bartlesville, Burge or Tucker sand by some drillers but is commonly not designated l any distinctive name.

The productive oil beds are the "Mississippi lime," two san (Nos. 9 and 10)[1] between the "Oswego lime" and the second Bi lime, a sand (No. 7) between the second Big lime and the Big lim and probably the Big lime itself.

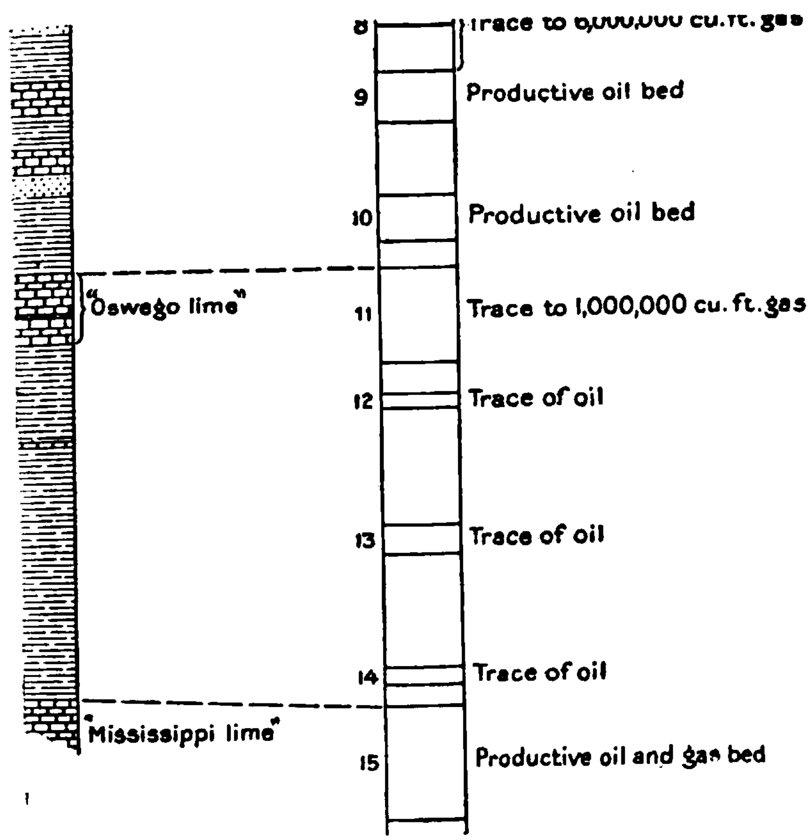
The "Mississippi lime" is the productive gas bed, but gas has als been found in quantities of as much as 6,000,000 cubic feet a day (initial production) in the "Oswego lime" and the second Big lime. A thin sand (No. 5) about 150 feet above the Big lime generally contains a small amount of gas. In one well a daily yield of 3,000,000 cubic feet of gas was reported from the top of the thick water-bearing sand (No. 4) 700 feet above the "Oswego lime," but so large a yield does not seem common at this horizon, most drillers simply reporting "gas" or "show of gas" from this sand. Two thin sands (Nos. 1 and 2) above the water-bearing sand contain traces of gas in some places.

STRUCTURE.

GENERAL ATTITUDE.

The rocks in this area show the low regional westward dip common to this part of Oklahoma. This dip is most pronounced in T. 28 N., R. 9 E. There are, however, many local exceptions to this general attitude in which the beds dip to the north, south, or east. These exceptions, especially those that involve a reversal or eastward dip in the rocks, are of particular importance to the oil geologist and driller, because they give rise to structural conditions favorable for oil and gas accumulation.

[1] These numbers refer to the corresponding beds in column 6, Pl. IX.



IN T. 28 N., RS. 9 AND 10 E., AND T. 29 N., R. 10 E.

The structure contours on Plate VIII, which depict the attitude of the rocks as seen at the surface, are drawn on a plane 20 feet below the middle bed of the Oread limestone.

ANTICLINES AND DOMES.

POND CREEK DOME.

In the following descriptions the anticlines and domes that have been drilled and developed are discussed first:

The Pond Creek dome covers an area of about 10 square miles lying mainly in the southeast quarter of T. 29 N., R. 10 E., and the northeast quarter of T. 28 N., R. 10 E. It is roughly circular in outline, with minor modifications on the west and southwest. It has a closure on the east of about 40 feet, and its crest lies near the center of sec. 3, T. 28 N., R. 10 E. It has long, gentle slopes on the north, south and east but comparatively steep slopes on the west, especially in the lobe projecting up Pond Creek, where the slope amounts to 70 feet in about half a mile. The long uninterrupted slopes to the north, south, and west afford a large collecting area from which a supply of oil and gas might have accumulated. As indicated by the wells whose locations are shown on Plate VIII,[1] the central part of the dome, covering an area of about 3 square miles, has been extensively developed by the Roxana (formerly Belmont) Petroleum Co., L. C. Duffield, and Foster & Davis. Other scattering wells have been drilled over a considerably larger area, especially to the south and east.

On the top of the dome, in secs. 34 and 35, T. 29 N., R. 10 E., and the N. ½ sec. 3, T. 28 N., R. 10 E., the oil has been obtained chiefly from sands 9 and 10 (see footnote, p. 48) between the second Big lime and the "Oswego lime," but some wells are reported to have obtained their oil from the Big lime. In this same area the gas has been obtained chiefly from the "Mississippi lime," though some wells have obtained considerable quantities of gas from the Big lime and the "Oswego lime." On the lower slopes of the fold, as at the south side of sec. 2, in the NW. ¼ sec. 3, and in secs. 10 and 11, T. 28 N., R. 10 E., so far as drilling has progressed, the shallow sands are dry and oil is obtained from the "Mississippi lime," which is either barren of gas or contains only a small quantity near the top of the limestone. An exception to this condition seems to exist on the eastern slope of the dome, where the "Mississippi lime" carries gas to the very bottom of the syncline and shows only traces of oil. These conditions indicate that in the shallow sands which do not contain gas the oil has accumulated on the crest and upper slopes of the fold, but that in the

[1] Most of the wells shown on the map were located during the progress of the field work; those not so located have been taken from plats furnished by the Bureau of Mines and the Empire and Barnsdall oil companies.

"Mississippi lime," which carries both oil and gas, the gas has accumulated chiefly on the crest and upper slopes of the fold and the oil on the lower slopes. This distribution of oil and gas in the same bed should be kept in mind when other folds in this area are drilled, for it is quite probable that where gas is found at the top of a fold oil will be found in the same bed farther down the slope, but where oil is found at the crest the same bed is likely to contain less oil or be dry or carry water farther down the slope.

The initial daily production of oil from the shallow sands ranges from about 10 to 260 barrels. From the "Mississippi lime" the initial daily production of oil is from 10 to 30 barrels and that of gas from 1,000,000 to 11,000,000 cubic feet.

The limits of the productive area of the Pond Creek anticline have not yet been determined. On the north and south slopes no dry holes have yet been drilled. On the west slope one dry hole has been obtained in the SW. ¼ NE. ¼ sec. 5, T. 28 N., R. 10 E., below the belt of steep dips shown on Plate VIII. As no record has been obtained for this well it is not known whether or not it was drilled to the "Mississippi lime," which it is necessary to reach in order to insure a complete test in this area. Since the field work was completed a dry hole (not shown on Pl. VIII) has been drilled near the northwest corner of sec. 12, T. 28 N., R. 10 E., seeming to indicate that the limit of the productive area on the southeast has been reached. On the east slope gas has been obtained from the ' Mississippi lime" in the bottom of the small syncline at the east side of sec. 1, T. 28 N., R. 10 E., which indicates that the sands will probably be productive across this shallow depression to a small dome about half a mile farther east. To the north, in sec. 36, T. 29 N., R. 10 E., two dry holes and one yielding only a small quantity of gas have been drilled. These holes were all drilled to the "Mississippi lime" and therefore indicate that on the northeast the productive area does not extend into the depression at the east side of sec. 36.

Columns 2 and 3 of Plate IX are logs of two wells drilled near the crest of the Pond Creek dome. They show the productive beds and the depths at which they occur.

WEST TURKEY CREEK ANTICLINE.

The West Turkey Creek anticline is a narrow fold about 2 miles long from northwest to southeast, lying mainly in secs. 13 and 24, T. 29 N., R. 10 E. It is practically continuous on the west with the broad, low North Caney River anticline. The east limb of the fold is broken by a small fault that trends north. The contouring of this anticline is based entirely on elevations taken on massive sandstones, which over a part of the fold are covered by a heavy growth of timber. Most of the work was done by M. I. Goldman, who also mapped the township to the east.

The Roxana Oil Co. and Mallory & Stewart have drilled about 14 wells on the west slope of this anticline, chiefly in the E. ½ sec. 23 and the NW. ¼ sec. 24. All but two of the oil wells shown on Plate VIII obtained their oil from a shallow sand (No. 7) below the Big lime and had an initial daily production of 25 to 60 barrels. A well about 600 feet west of the east quarter corner of sec. 23 was drilled to the "Mississippi lime" in the expectation of finding gas but obtained instead a much larger supply of oil than is obtained from the shallow sand. Another well, near the southwest corner of the NW. ¼ sec. 24, a log of which is shown in column 4, Plate IX, obtained oil in the shallow sand and both oil and gas in the "Mississippi lime," but the quantity is not given in the well log. The depth to the shallow sand in these wells is about 1,080 feet and to the "Mississippi lime" about 1,770 feet. These two examples indicate the desirability of drilling to the "Mississippi lime" after the shallow sand has been exhausted or where it is found to be dry.

The limits of production on the northeast will probably not reach the depression in the NE. ¼ sec. 13, as two dry holes, at least one of which reached the "Mississippi lime," have been put down there and another in the northeast corner of sec. 24. On the southwest a dry hole in the Mississippi lime" was drilled in the northeast corner of sec. 26 and one in the shallow oil sand near the south quarter corner of sec. 23. About 4,000,000 cubic feet of gas (initial production) was obtained from the "Mississippi lime" in a well about the center of the SE. ¼ sec. 23.

NORTH CANEY RIVER ANTICLINE.

The North Caney River anticline crosses the Oklahoma-Kansas line at the north side of sec. 16, T. 29 N., R. 10 E., and continues southeastward into secs. 15, 14, and 23, where it merges with the West Turkey Creek anticline. From the point where it crosses the State line this fold continues on the Kansas side in a direction slightly north of west, probably to a point about north of the north quarter corner of sec. 18, and therefore within a mile of the town of Elgin, Kans. So far as could be determined, the fold has no easterly dip and is therefore in the nature of a "nose" pitching to the northwest. Its relation to the structure on the north was not determined, but on the southwest there is a large gathering ground from which oil and gas may have been obtained.

The greatest development in this fold has been in the N. ½ secs. 15 and 16 and northward across the Kansas line. With one exception the wells on the Oklahoma side have all been gassers that obtained their supply from the "Mississippi lime," which was reached at a depth of 1,700 to 1,775 feet, the depth depending on the topographic location of the well. In several of the gas wells a show of oil was also obtained from the "Mississippi lime." A well drilled about 900 feet west and 500 feet south from the north quarter corner of sec. 16, and therefore somewhat farther down the slope than the other wells shown on Plate IX, obtained an initial production of 25 barrels of oil and 100,000 cubic feet of gas from the "Mississippi lime." The gas-producing area extends southeastward probably without interruption to the Turkey Creek anticline. Dry holes in the valley of Caney River in sec. 21, one of which is known to have reached the "Mississippi lime," indicate that the productive area will probably not extend as far south as the shallow syncline lying just north of the river. If the conditions are the same in this fold as in the Pond Creek dome, oil should be found in the "Mississippi lime" between the area of gas production along the crest of the anticline and the bottom of the syncline to the south.

WEST MISSION CREEK DOME.

The West Mission Creek dome lies in secs. 26, 27, and 34, T. 28 N., R. 10 E. It is oval in outline, and its major axis has a northeast-southwest extent of about 2 miles. The crest of the dome lies near the east side of sec. 27, and it has a closure on the east of about 40 feet. The slopes to the south and west are steep, especially in their lower parts; that to the north is gentle, merging with a broad terrace. The fold is limited on the southeast by a deep syncline that separates it from the East Mission Creek dome, on the southwest by a narrow saddle that separates it from a large anticline in T. 27 N., R. 10 E., and on the west by a shallow depression that separates it from the Rattlesnake anticline. The chief area from which oil and gas may have been gathered for the West Mission Creek dome is therefore the broad, flat terrace to the north, and smaller quantities may have accumulated from the territory near by on the west.

The dome has been partly developed by the Osage Natural Gas Co., whose wells are mainly on the crest and north slope of the fold. No oil has been obtained; the initial daily production of gas ranges from 750,000 to 4,500,000 cubic feet and is obtained from the "Mississippi lime" at an average depth of about 1,900 feet. Traces of oil from sands 7, 10, and 14 and also from the "Mississippi lime" have been reported in the logs of some of the wells. A log of one of these wells is shown in column 5, Plate IX.

Dry holes which reached the "Mississippi lime" have been put down in the syncline to the south, in secs. 25 and 35. It is probable, therefore, that the productive area will not extend to the base of the steep slope on the south. The dry hole near the south quarter corner of sec. 27, which seems to have reached the "Mississippi lime," is difficult to explain, as it is located practically on the crest of the fold. At least one other hole should be drilled on the west end of the dome before it is abandoned. The dry hole a little northeast of the west quarter corner of sec. 26 has no significance, as the tools were lost, and the hole was abandoned at a depth of 695 feet. The other two dry holes on the north slope of the dome, in secs. 26 and 27, reached the "Mississippi lime" and therefore seem to be fair tests. From the evidence at hand it seems that the prospects of obtaining oil in the "Mississippi lime" on the lower slopes of this dome are not so good as in the other folds thus far discussed. Should other tests be made, especially on the north and west slopes, there is reasonable hope of finding oil.

EAST MISSION CREEK DOME.

The East Mission Creek dome occupies the SE. ¼ sec. 25 and most of sec. 36, T. 28 N., R. 10 E., and extends eastward into secs. 30 and 31, T. 28 N., R. 11 E., a report on which is given in another chapter of this bulletin. The crest of the dome lies about 1,000 feet west-northwest of the east quarter corner of sec. 36; the closure on the east amounts to 20 or 30 feet. The dome has a fairly good gathering ground to the north but very little to the west and south. It has not been developed, but the conditions here are probably somewhat similar to those on the West Mission Creek dome. The depth to the "Mississippi lime" at the crest of the dome is probably about 1,750 or 1,800 feet.

RATTLESNAKE ANTICLINE.

The Rattlesnake anticline lies northwest of Rattlesnake Spring and occupies parts of secs. 19, 20, 21, 29, and 30, T. 28 N., R. 10 E., and secs. 25 and 36, T. 28 N., R. 9 E. Its longest axis trends northeast, is about 4 miles long, and pitches to the southwest at an average rate of about 25 feet to the mile, but at the extreme southwest end the pitch is 80 feet to the mile. The fold is chiefly of the plunging anticlinal nose type, but seems to have a closure of about 10 feet at its extreme northeast end, in sec. 21. It has a large gathering ground to the northwest, west, and southwest.

Evidence regarding the amount of development on this fold is somewhat conflicting. The plats obtained from the Empire Oil Co. and the Bureau of Mines show four dry holes, all fairly well placed in the fold, at the southwest corner of sec. 20, the northwest corner of sec. 28, the southeast corner of the SW. ¼ sec. 21, and the southeast corner of the NW. ¼ sec. 21. The plat obtained from the Barnsdall Oil Co. shows but two of these holes, one in the northwest corner of sec. 28, which is recorded as a gas well, and a dry hole in the southeast corner of the SW. ¼ sec. 21. In the field the writer succeeded in finding but one of these four holes, that in the southwest corner of sec. 20. The hole is dry, and from the log filed at the Indian Office it evidently reached the "Mississippi lime." If the four holes shown on Plate VIII have all been drilled and all reached the "Mississippi lime," it would seem that the anticline has been fairly well tested, and that if any further drilling is done it should be farther down the slopes of the fold or on its extreme southwest end. On the other hand, if only the hole in the southwest corner of sec. 20 has been drilled, at least one other test should be made on the highest part of the fold, about the center of the SW. ¼ sec. 21. There is some room for doubt whether the three holes referred to above not found by the writer were actually drilled. No record of any of them has ever been filed at the Indian office at Pawhuska. An abandoned oil well in the southwest corner of sec. 28 is reported by two of the authorities given above, but on visiting this locality the writer found the remains of a derrick but no evidence of a hole nor any indication (such as a sludge pile) that any drilling had ever been done here. Inquiry among ranchers near by disclosed the fact that a derrick had been built there but that no drilling had ever been done and that the derrick was finally blown down. The occurrence of a 10-barrel oil well on the Spring Creek dome, about three-quarters of a mile north of the crest of the Rattlesnake dome, is at least suggestive that some oil should be found in the latter.

SPRING CREEK DOME.

The Spring Creek dome lies on a tributary of Spring Creek in the SW. ¼ sec. 16, T. 28 N., R. 10 E. It is a small dome having a closure of only 10 feet. A 10-barrel well on the southwest end of this fold, which obtained oil at a depth of 1,820 feet, probably from the "Mississippi lime" or a thin sand immediately above it, is the only one thus far drilled. A 30-barrel well in the northeast corner of sec. 16 is more closely related to the Pond Creek dome than to the Spring Creek dome. It suggests, however, that the entire saddle between the two folds may contain oil.

BIRCH CREEK TERRACE.

A broad terrace on which there are a few minor protuberances occupies the area in T. 28 N., R. 10 E., bounded on the north and northeast by the Pond Creek dome and the syncline lying southeast of it, on the south by the West Mission Creek dome, and on the west by the Spring Creek dome. The outline of this terrace, which may be called the Birch Creek terrace, is based on elevations taken on various beds of a thick sandstone series, for the most part covered with timber. Some allowance should therefore be made as to details.

One dry hole has been drilled on the terrace near the west quarter corner of sec. 24. No record is available to show the depth of the hole, and its value as a test is therefore not known. It seems probable that if oil and gas were originally present in this terrace they would have migrated for the most part to the domes surrounding it, and that it is therefore not a promising place in which to obtain oil or gas. It may be, however, that small local pools have accumulated in the minor protuberances on the surface of the terrace.

DIVIDE DOME.

The Divide dome occupies parts of secs. 12 and 13, T. 28 N., R. 9 E., and secs. 7 and 18, T. 28 N., R. 10 E. Its crest is on top of the high timbered divide which trends northeast through this part of the area, and it has a closure of only 10 feet. The outline of the dome is based mainly on elevations taken on the middle bed of the Oread limestone. In addition to the main dome there seems to be a long, narrow southward-trending spur extending across sec. 13 and into sec. 24, T. 28 N., R. 9 E. The outline of this spur is based partly on elevations on the Oread limestone and partly on beds in the Elgin sandstone. The dome has a large gathering ground to the west. No wells have been drilled on it. Its crest is capped by the Elgin sandstone (partly eroded), and the "Mississippi lime" should therefore lie at a depth of about 2,150 feet beneath it. A test hole placed about the center of the SW. ¼ sec. 7 would be on about the highest part of the dome, but considerable advantage in drilling could be obtained by choosing a location farther west, near the west side of the section and below the rim of Elgin sandstone.

RICEROCK ANTICLINE.[1]

The Ricerock anticline lies in secs. 7 and 18, T. 28 N., R. 9 E., and secs. 12 and 13, T. 28 N., R. 8 E. The axis trends a little north of west from the south quarter corner of sec. 7, T. 28 N., R. 9 E., to the east quarter corner of sec. 11, T. 28 N., R. 8 E. From this axis the beds dip northwest and southwest. To the east the fold dies out in a flat terrace almost a mile broad, which on the east merges with the regional dip. The steepest dip on the fold is on its tip, where the beds incline to the west about 80 feet to the mile. On the flanks the dips probably average about 60 feet to the mile. The formation capping this anticline is a sandstone about 20 feet above the "red lime" in the stratigraphic column. A thin bed of lime-

[1] The descriptions of the Ricerock anticline, Upper Pond Creek dome, and Limestone Flat terrace were supplied by K. C. Heald.

stone, thickly filled with tests of *Fusulina*, was of great assistance in mapping the structure, as it furnished an easily identified, thoroughly reliable horizon on which to determine the relative elevations of different parts of the fold.

The doming of this fold is so slight that it is in effect more of a terrace than an anticline, and the chance that it has induced the formation of a large pool of oil is comparatively slight. If there is such an accumulation it is probably confined to the west flank of the fold. Accordingly a good location for drilling would be about the center of the SE. ¼ SE. ¼ sec. 12, T. 28 N., R. 8 E. The depth to the "Mississippi lime" at this point should be about 2,200 feet.

UPPER POND CREEK DOME.[1]

The Upper Pond Creek dome lies in sec. 19, T. 28 N., R. 9 E. It is a low, almost imperceptible bulge, bounded on the northeast by a small fault with a throw of 10 feet or less. Dips on the other flanks average about 60 feet to the mile. A cross section of this fold from northwest to southeast would show a very low, flat arch. One from southwest to northeast would show half such an arch abruptly terminated by a vertical fault scarp.

The shape and outline of this dome were determined by elevations on several of the resistant limestone beds of the Pawhuska formation. The bed that caps the fold is the first heavy limestone below the "red lime."

This anticline is so low that its effect in arresting the migration of oil has probably been slight. The most promising place for a pool is on the west flank of the fold, where the beds dip westward at a fair rate. Accordingly the center of the SW. ¼ SW. ¼ sec. 19 is suggested as a good location for drilling a test well. At this place the "Mississippi lime" should lie about 2,100 feet below the surface.

LIMESTONE FLAT TERRACE.[1]

In sec. 32, T. 29 N., R. 9 E., and secs. 5 and 8, T. 28 N., R. 9 E., there is a marked change in the rate of the regional westward dip, the rocks flattening out toward the west, making a terrace about 1 mile broad and 3 miles long. At the south end of this terrace is the Ricerock anticline described above. The terrace is not absolutely horizontal but slopes to the west at a rate of about 10 feet to the mile. On its surface there are two very small anticlines and at least one correspondingly small syncline, but these features are relatively minor parts of the terrace as a whole. The rock that caps the terrace is the highest bed of the Pawhuska lime-

[1] The descriptions of the Ricerock anticline, Upper Pond Creek dome, and Limestone Flat terrace were supplied by K. C. Heald.

stone, and the elevations that proved the existence of the terrace were taken on the limestone ledges that make up the Pawhuska limestone. At its west edge the rocks forming this terrace pitch to the west at a rate of about 60 feet to the mile, and at the east edge they rise to the east with a somewhat gentler slope.

The structure of this terrace is not such as to influence any great accumulation of gas or oil, and any wells that may be found on it will probably have a small initial production. The most promising part of the terrace is the region of moderately steep dips west of the flat top of the flexure. Accordingly the center of the NW. ¼ sec. 7, T. 28 N., R. 9 E., is suggested as a good location for drilling a test well. The depth to the "Mississippi lime" here should be about 2,150 feet.

MINOR FOLDS AND TERRACES.

There are several minor anticlines in this area, most of them without any closure on the east, and some terraces in which there is a possibility of finding oil or gas. Most of these minor features are wholly undeveloped. Attention is called to them here in the belief that they are the most favorable places to test after the areas described above have been drilled.

One of these small anticlines occurs in the S. ½ sec. 29, T. 29 N., R. 10 E., and another in sec. 31, extending west into sec. 36, T. 29 N., R. 9 E. The latter has well-defined south and west dips but very little dip to the north. The "Mississippi lime" should be reached on these folds at 1,900 to 2,000 feet.

A small dome is shown near the center of sec. 4, T. 28 N., R. 10 E., with a nose extending southwestward into sec. 5. The chief evidence for the existence of this dome consists in pronounced reverse dips in the sandstones on opposite sides of Spring Creek. On the northwest side of the creek the sandstone dips northwest at an angle of about 15° for a distance of about 1,000 feet. Dips of this magnitude in the Pawhuska quadrangle usually indicate faulting, but no definite evidence of a fault could be found here. On the southeast side of the creek near the center of the section the sandstone dips to the southeast at a low angle. The sandstones are badly broken and difficult to trace with certainty in this part of the area, so that the evidence of reverse dips is not strongly supported by elevations on the beds. In this dome the "Mississippi lime" lies at a depth of about 1,800 feet in the valley of Spring Creek.

A small anticline that shows dips on the north, south, and west but merges into a flat or terrace on the east occurs in sec. 3, T. 28 N., R. 9 E. It has not been drilled, but the "Mississippi lime" is estimated to lie at a depth of 2,200 feet below it.

Four holes have been drilled in the northwest corner of sec. 22 and the northeast corner of sec. 21, T. 28 N., R. 9 E., in a narrow belt of steep westward dips with a flat or terrace above and below. One of the wells obtained a little oil and gas and would probably yield enough to pay for pumping if there were any other wells in the vicinity; the other three holes are dry. These wells were drilled several years ago, and as no record of them seems to have been kept it is not now possible to ascertain even the depth to which they were drilled. If they penetrated the "Mississippi lime" there would be little inducement for further drilling at this place. On the other hand, if they did not reach the "Mississippi lime" it would be very desirable to continue one of them down into that formation, which should be reached at a depth of about 2,000 feet in the well where the show of oil and gas was obtained. It is probable that the holes were not drilled deeper than the "Oswego lime," because at the time of drilling oil was being obtained from the "Oswego" or a sand about 400 feet above it in the Elgin field, about 7 miles farther north. The occurrence of even a small quantity of oil here is interesting, because it seems to bear out what has been observed in at least two other places [1] in the Pawhuska quadrangle—in sec. 20, T. 29 N., R. 9 E., and sec. 22, T. 24 N., R. 10 E.—namely, that there is a tendency for oil to accumulate in belts of steep westward dip bordered above and below by terraces.

A terraced area similar to the one just described but much more pronounced, having a westward dip of 60 feet in half a mile and bordered above and below by a broad flat, occurs in secs. 29 and 32, T. 28 N., R. 9 E. If future experience demonstrates that structural features of this character are likely to contain oil or gas, this one would certainly be worth testing.

[1] Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 88–89, 1918 (Bull. 691–C).
Bowen, C. F., report on T. 24 N., R. 10 E., in this volume (Bull. 686–D).

T. 25 N., R. 10 E.

By Dean E. Winchester, K. C. Heald, and others.

INTRODUCTION.

The field work on T. 25 N., R. 10 E. (see fig. 1), was done by Dean E. Winchester, K. C. Heald, E. Russell Lloyd, and J. P. Buwalda. The areas covered by the different geologists are shown on Plate X. The elevations on the key beds and the exact locations of their outcrops were determined by plane-table surveying, except those on a small area in the southeastern part of the township, where barometers were used to determine elevations, pacing to determine horizontal distances, and compasses to determine directions. In this barometric work all the results were checked by two observers, and any results that appeared to be the least bit doubtful were discarded.

KEY ROCKS.

General features.—The exposed rocks in this township (see fig. 12) are of upper Pennsylvanian age and include sandstones, limestones, and shales. Sandstones form more than half the total thickness of the exposed rocks, but there are also thick beds of shale, particularly in the extreme southeast corner of the township. Limestones are very inconspicuous.

A comparison of the contouring of the structure in T. 25 N., R. 10 E., and that in T. 26 N., R. 10 E., reveals a failure of the contours in the two townships to join exactly. This is not due to faulty observation but rather to the fact that the geologists working in these townships based their work on different assumptions. In T. 26 N., R. 10 E., it was assumed that the key beds are approximately parallel to the middle bed of the Oread limestone, which is well exposed along the west line of the township and is the only part of the Oread represented here, and for most of the township there can be no doubt that this assumption is essentially correct. In T. 25 N., R. 10 E., it was assumed that most of the beds are parallel to the Labadie limestone, and here also the work shows that the assumption is correct. However, there is a convergence between the middle bed of the Oread limestone and the Labadie limestone, and because of this convergence the contouring in the two townships does not exactly connect.

Cochahee sandstone.—The Cochahee sandstone, named from its good exposures on the headwaters of Cochahee Creek, in the southwestern part of T. 25 N., R. 10 E., is a thin, flaggy bed about 45 feet above the Labadie limestone and 125 feet below the Oread limestone. It is very well exposed near Nelagoney, where it forms a rim capping the hill on whose flanks the town is built and shows as a well-defined ledge on the hill slopes overlooking Saucy Calf Creek just northwest of Nelagoney. It is here less than 3 feet thick, although in other places thicknesses of 10 to 25 feet have been noted. The sandstone is massive, hard, and fossiliferous and has a peculiar weathered surface suggesting turkey tracks. This peculiar surface and the fossil *Fusulina*, which in places are extremely abundant in this bed, are its most characteristic features.

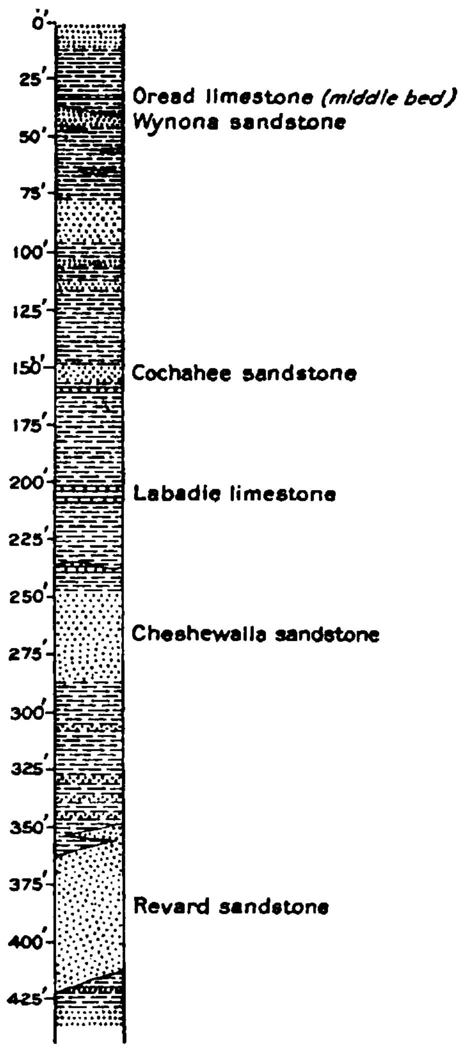


FIGURE 12.—Section of rocks exposed in T. 25 N., R. 10 E.

The Cochahee sandstone was particularly useful in determining the structure in the southwestern portion of the township. (See Pl. X.)

Labadie limestone.—The Labadie is the first limestone of any prominence below the Oread limestone, which is about 180 feet stratigraphically above it. In the northern part of T. 25 N., R. 10 E., it consists of two benches of limestone, each about 2 feet thick, separated by about 10 feet of gray shale. It is not conspicuous in this township and must be traced more by the vegetation, which is of a different character on the lime-impregnated soil from that on sandy soil above and below, than by actual outcrops of the limestone itself.

The outcrop of this bed could not be recognized west of Bird Creek. Lentils of limestone occur at about the horizon which it should occupy, but they show no characteristics which would make an accurate correlation possible. East of Bird Creek there are several good exposures, and it may be traced northwestward to the north line of the township. (See Pl. X.)

The Labadie limestone is both overlain and underlain by gray shale in which are thin beds of sandstone. Some of these thin sandstones are persistent and may be followed with much greater ease than the limestone. One which is about 11 feet below the limestone was particularly helpful in determining the structure in the northeastern part of the township.

Cheshewalla sandstone.—The first heavy bed of massive sandstone below the Labadie limestone is the Cheshewalla. Between it and the limestone are about 60 feet of shale and thin, hard sandstones, and in a few localities there is also a very thin limestone a few feet above the top of the Cheshewalla.

The lithology of the Cheshewalla sandstone is not distinctive enough to permit its identification by this means. It is fine grained, moderately well cemented, rather soft, and cross-bedded. Only a few fossils were noted in it, although there are fossiliferous sandstones both above and below it, and the base of the Cheshewalla itself carries a pelecypod fauna in some localities. Plant fragments are fairly common in it, but they are so thoroughly macerated that they can not be identified.

This sandstone is 20 to 50 feet thick and along most of its outcrop in this township appears as a single heavy bed without interbedded shale. However, it contains local lentils of red shale a mile or less in length, which cause the formation of benches. Such benches are traceable for short distances but are not reliable as horizon markers, as they pinch out most unexpectedly. Moreover, there is a constant temptation to pass over an area where a bench is obscured by talus and to pick up another bench on the other side of the obscure area, correlating the two and continuing the mapping on this basis. Actually there is little need to do this, for the top of the Cheshewalla may be followed very easily. In many localities there is a thin fossiliferous sandstone a short distance above it which makes the identification of the horizon certain. The base of the Cheshewalla may also be followed in parts of the township, but better results may be obtained by tracing one of the thin sandstones that underlie it.

This sandstone is very well developed near the point where Cheshewalla Creek empties into Nelagoney Creek, in the SE. ¼ sec. 9. It also shows up well below the bridge of the Missouri, Kansas & Texas Railway over Bird Creek, northeast of Nelagoney.

Revard sandstone.—The Revard sandstone, which lies about 145 feet below the Labadie limestone, is particularly prominent in the southeastern part of this township. It is 30 to 80 feet thick and consists of massive sandstone very similar to the Cheshewalla sandstone, with lentils of red shale. The shale lentils range in length from a few feet to a mile or more and in thickness from a few inches to 6 feet.

The Revard sandstone is one of the most persistent sandstones in the Pawhuska quadrangle, but in this township it is not a particularly good bed upon which to base structure contouring. The top of the sandstone is not clearly defined, nor is it confined to a single definite horizon. Locally the red shale which directly overlies the Revard sandstone is replaced by lentils of heavy sandstone (see fig. 13), and this introduces the possibility of error in mapping, for there

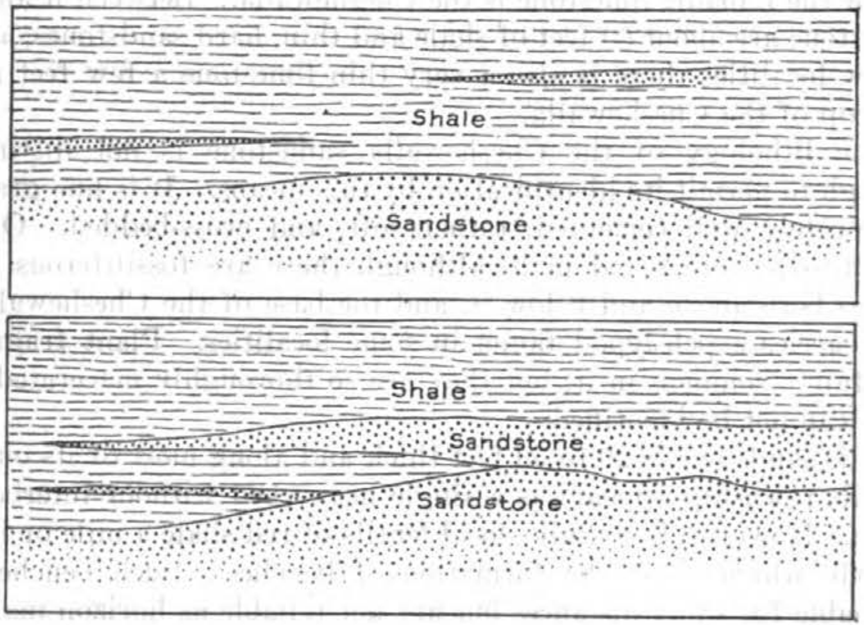


FIGURE 13.—Sketches illustrating observed instances of irregularity in the upper surface of the Revard sandstone in the southeastern part of T. 25 N., R. 10 E.

may be a difference of 30 feet in the total thickness of massive sandstone at points a quarter of a mile apart. Fair results may be obtained by following some of the shale lentils, but they are so short and so likely to be concealed by débris from the overlying beds that they are not very satisfactory as horizon markers. Wherever possible the thin sandstone beds a little below the base of the sandstone series should be utilized. Some of these beds are very persistent and have characteristics that render even isolated outcrops identifiable; for example, some beds carry quantities of small *Fusulina*, and other beds form benches that are definite enough to be traced for considerable distances. In places the base of the massive sandstone may be easily traced, for it is distinctive, being coarser and darker than the upper parts of the Revard sandstone and containing shale inclusions and numerous hollows and pits which presumably were originally occupied by such inclusions.

The type locality for this sandstone is at Revard Point, in sec. 13, T. 26 N., R. 10 E. A good reference locality is on the bluff facing Bird Creek due east of the town of Quapaw, in the NE. ¼ SE. ¼ sec.

36. T. 25 N., R. 10 E. Here the top of the Revard sandstone is about 45 feet below the top of the hill.

PENNSYLVANIAN ROCKS BELOW THE SURFACE.

The unexposed rocks above the "Mississippi lime" are of the same general type as those which appear on the surface. Sandstone

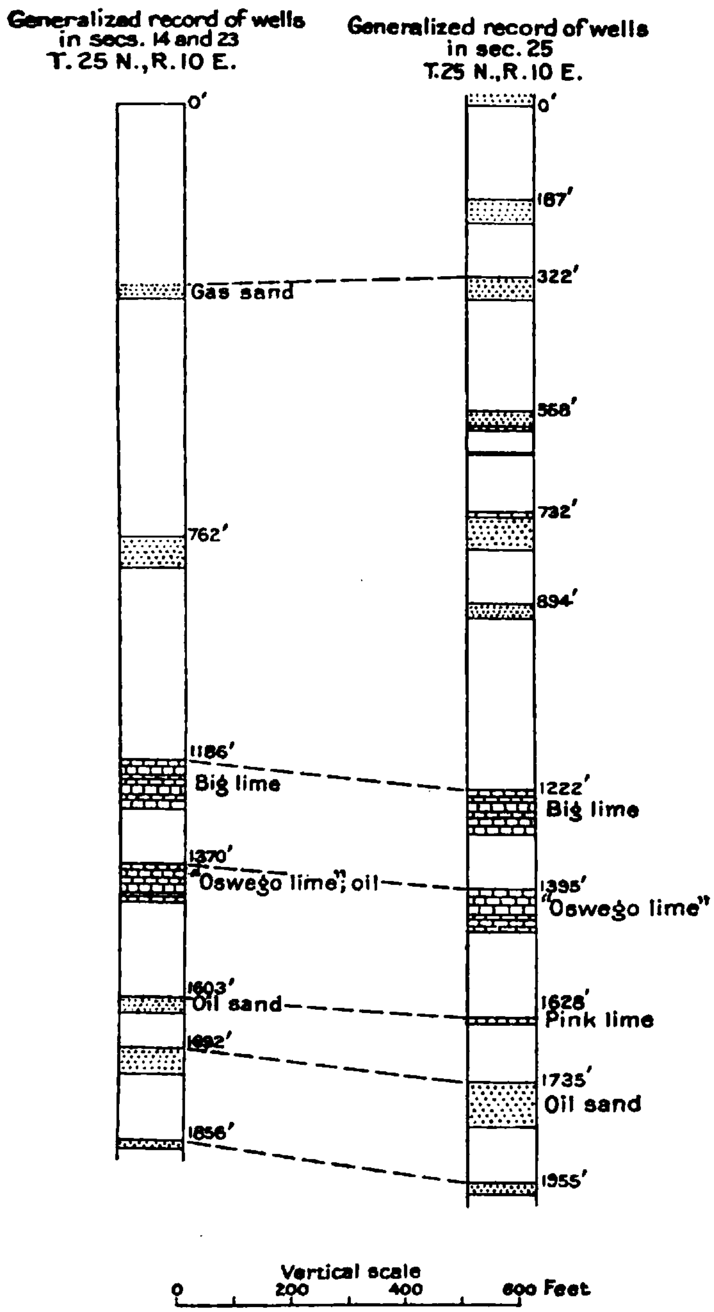


FIGURE 14.—Generalized records from wells in secs. 14, 23, and 25, T. 25 N., R. 10 E.

and shale make up about 90 per cent of the total above what is known to the driller as the Big lime (probably the Pawnee limestone of the Kansas section). Below that horizon there is comparatively little sandstone but there are massive beds of limestone and much shale. Many of the sandstones in the upper part of the section are water bearing, even on pronounced anticlines, and in some of the synclines they yield quantities of either fresh or salt water.

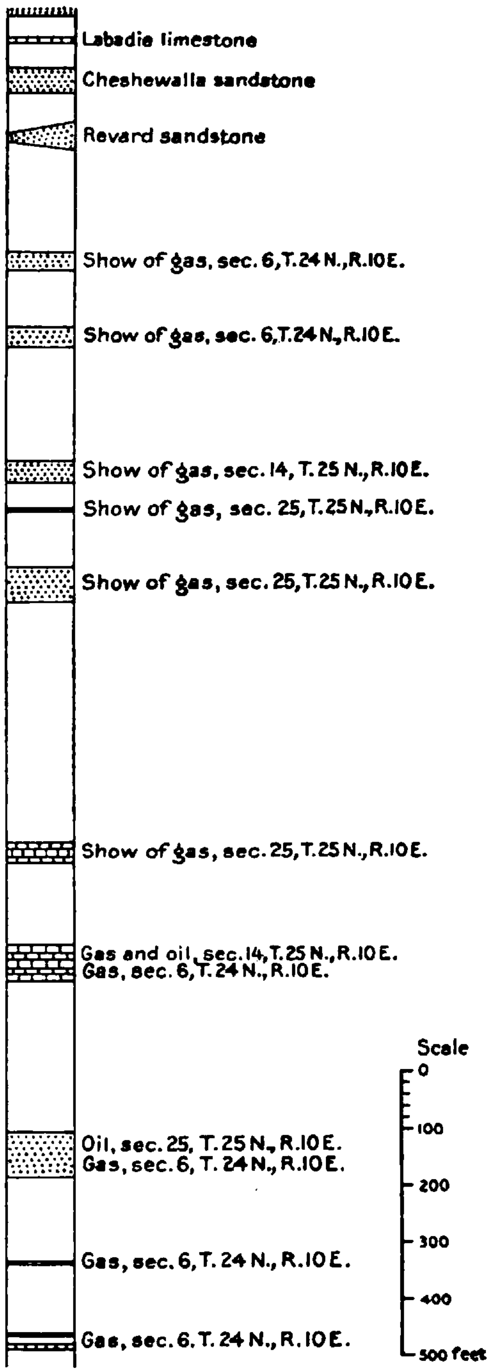


FIGURE 15.—Section showing principal key beds and sands which have yielded oil or gas in T. 25 N., R. 10 E., or in immediately adjacent territory.

Either oil or gas has been found in at least ten distinct beds in the wells which have been drilled in this township. (See figs. 14 and 15.) Most of these beds contained only "showings," which were not large enough to be commercially important, although they indicate the possibility of valuable production from the beds in which they were found, but several beds have contained sufficient oil or gas to justify the expense of drilling and equipping wells. The "Oswego lime" (Fort Scott limestone), the Bartlesville sand, a sand a little below the top of the "Mississippi lime," and a sand about 300 feet below the top of the "Mississippi lime" have all yielded gas in commercial quantity, and oil has been produced from the Fort Scott ("Oswego") limestone and from the Bartlesville sand.

STRUCTURE.

The general structure in T. 25 N., R. 10 E., is fairly simple. There is a pronounced regional dip a little to the north of west, modified by a few cross folds that introduce east and south dips and accentuate the dips to the north, but over most of the township the westerly dip dominates the structure.

The term "closure" as used in this report may for all practical purposes be taken to mean the vertical distance between the highest and lowest closed contours on the anticline plus the contour interval—that is, if the highest closed contour represents an elevation of 900 feet, the lowest closed contour an elevation of 880 feet, and the contour interval (vertical distance between successive contours) is 10 feet, the closure is approximately 30 feet.

ANTICLINES, DOMES, AND TERRACES.

KIHEKI DOME.

The highest point on the Kiheki dome is in the NW. ¼ sec. 10. The major axis extends northeastward into sec. 3 and southwestward

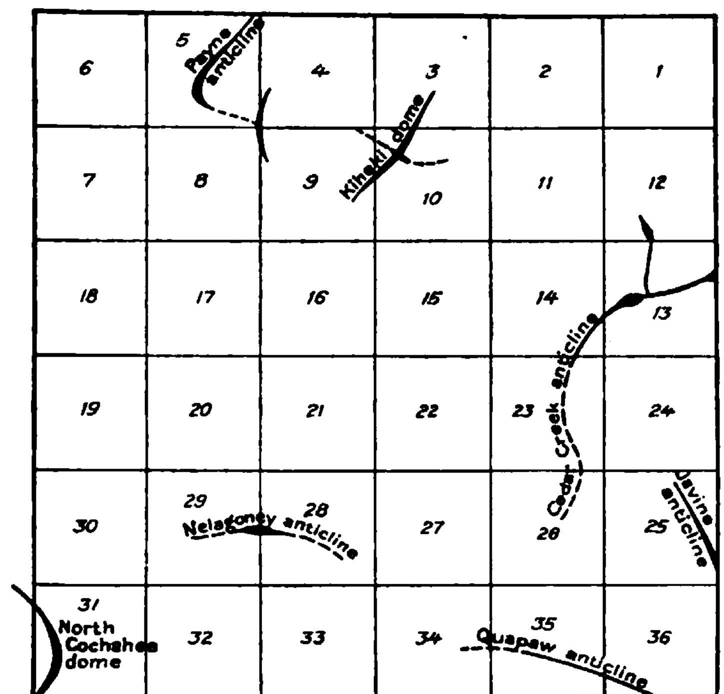


FIGURE 16.—Diagram showing approximate position of anticlinal axes in T. 25 N., R. 10 E.

into sec. 9. (See fig. 16.) The closure is 20 feet. The lowest and gentlest dips are on the southeast flank of the fold; on the other flanks the dips are much steeper. The area covered by this dome is small compared to that of many of the Osage County anticlines, for the lowest closed contour encircles a little less than half a square mile, and the territory over which the structure might be expected to exert an influence on the accumulation of oil or gas is probably a square mile or less.

A single well has been drilled on the Kiheki dome. It was drilled to the "Mississippi lime" and passed through all the beds which are productive of oil in other parts of this township. Near the bottom of the hole it pierced a gas-bearing stratum which it was estimated would yield between 1,500,000 and 2,000,000 cubic feet a day. This yield was not considered sufficient to justify laying pipe to utilize it, and accordingly the hole was plugged.

The general experience in the Osage country has been that terraces and broad, low anticlines are more likely to be productive on the steeply dipping parts of the flanks than on the flat step of the terrace or the crown of the anticline. It therefore seems that there is much more likelihood that oil will be found in the SW. ¼ sec. 3, the SE. ¼ sec. 4, and the NE. ¼ sec. 9 than in the NW. ¼ sec. 10, where the test well mentioned above is located. (See Pl. X.) On the other hand, the crowns of the domes similar to the Kiheki dome are almost invariably occupied by gas, and it is very probable that further drilling in the NW. ¼ sec. 10 will result in gas wells that will be worth maintaining.

Good locations for test wells on this dome are the center of the NE. ¼ NE. ¼ sec. 9 and the extreme southeast corner of sec. 4. A well drilled at the first-named locality should strike the Fort Scott ("Oswego") limestone at a depth of 1,500 to 1,550 feet. There is a possibility that oil will be found at this horizon or a little lower. The Bartlesville sand, if present, should be encountered at about 1,850 to 1,900 feet. The hole should be carried to a depth of at least 2,300 feet if oil is not obtained at less depth, for it is known that in other parts of the Osage Reservation there are productive sands which, if present here, are at least that far below the surface.

PAYNE ANTICLINE.

The Payne anticline is a low, inconspicuous fold whose curved axis passes through parts of secs. 9 and 5, T. 25 N., R. 10 E., and into sec. 32, T. 26 N., R. 10 E. (See fig. 16.) Along this axis there are two distinct domelike humps where the rocks are arched slightly higher than elsewhere along the axis. The center of the southern of these humps is very near the southeast corner of sec. 5; the other is in the NW. ¼ SE. ¼ sec. 5.

The arch of this anticline is extremely flat. The closure is only 10 feet, and the rocks do not pitch steeply on the flanks of the fold. It would be classed as a terrace except for the presence of the two small humps mentioned above. Nevertheless the area over which it is believed this anticline may influence the accumulation of oil or gas is considerable, including part of the SE. ¼ sec. 4, most of sec. 5, the NE. ¼ sec. 8, and a small part of the NW. ¼ sec. 9.

Two wells that have been drilled near this anticline do not make it appear particularly favorable as a possible reservoir of oil and gas. The well on the Kiheki dome has been discussed above. A well was drilled to the north, in sec. 32, T. 26 N., R. 10 E., by the Texas Co. in 1918. This test was not well located with respect to the structure, as it was far down on the south flank of a small anticlinal fold and was much closer to the axis of one of the marginal synclines than it was to the crest of the anticline. It was drilled to the "Mississippi lime" without obtaining a commercial flow of gas, although at least three sands yielded small amounts.

A well was drilled in the extreme northeast corner of sec. 7 some years ago. No facts concerning this test beyond its failure to encounter either oil or gas are now available, so it is not known whether or not it was drilled deep enough to pierce the sands which it is believed may carry oil or gas. However, the location of the well is extremely unfavorable, as it lies very close to the axis of a pronounced syncline, and its failure is not surprising.

In wells drilled on the Lookout anticline, less than 2 miles west of the Payne anticline, the Fort Scott ("Oswego") limestone or a sand associated with it has yielded large volumes of gas and a well drilled to the "Mississippi lime" had an initial daily production of about 25 barrels of oil.

From the size and shape of the Payne anticline and the gathering ground from which oil and gas may have migrated to accumulate under the anticline, it appears probable that gas will be found in paying quantity, and at least it is possible that the anticline will yield oil, although probably no large wells will ever be brought in here. Good locations for tests are near the center of the NE. ¼ SW. ¼ sec. 5 and in the center of the NE. ¼ NE. ¼ sec. 8. At these locations the Fort Scott ("Oswego") limestone should be between 1,500 and 1,700 feet below the surface, and the Bartlesville sand, if it is present, about 300 feet deeper.

LOOKOUT ANTICLINE.

The highest point on the Lookout anticline lies near the northwest corner of T. 25 N., R. 10 E., and the structure outlined by the closed contours covers territory in all four of the townships cornering here. The dips on all sides are pronounced. The closure is about 40 feet, and the territory which appears favorable for oil accumulation is about 2 square miles. Only a small part of this fold lies in T. 25 N., R. 10 E., and that part is not pronouncedly favorable for oil or gas, as it is on the southeast flank of the anticline, and the general experience in Osage County is that the west and northwest flanks of the anticlines are the portions most likely to contain oil.

Two wells have been drilled on the Lookout anticline. Both are near the top of the fold and constitute good tests, although neither was carried deep enough to test all the possibly productive sands. One of these tests, in the southeast corner of sec. 36, T. 26 N., R.

9 E., obtained a large volume of gas from shallow sands and a particularly heavy flow from the Fort Scott ("Oswego") limestone. The other, in sec. 31, T. 26 N., R. 10 E., was drilled through the horizons of the gas-bearing sands of the first-mentioned well and obtained oil from the "Mississippi lime." The initial production of this well was reported to be 25 barrels.

The size, shape, and location with respect to regional structure of this anticline lead to the conclusion that probably no very large wells will be developed on it. However, wells of moderate size may be expected. The best location on that part of the anticline which lies in T. 25 N., R. 10 E., appears to be the extreme northwest corner of sec. 6.

CEDAR CREEK ANTICLINE.

Only a portion of the Ceder Creek anticline lies in T. 25 N., R. 10 E. Its axis runs from the central part of sec. 26 northward and eastward and crosses the line into T. 25 N., R. 11 E., a little north of the middle of the east line of sec. 13. There are several gentle cross folds on it, the most pronounced of which joins the axis of the main anticline a little west of the center of sec. 13. (See fig. 16.) Only a single contour closes on that part of the anticline which is in T. 25 N., R. 10 E., and this one is of little significance, as it surrounds a very small upward bulge with a total area of less than 40 acres. However, the top of the anticline is very flat, and this fact makes it appear improbable that oil or gas in any quantity may have migrated along the axis and escaped to the east.

The productivity of this fold has already been demonstrated. Several oil wells and one gas well were drilled on or near its axis in the southern part of sec. 14 and the northern part of sec. 23 in 1910 and 1911 and were productive until 1915, when they were abandoned. These wells had initial yields of 10 to 50 barrels from the Fort Scott ("Oswego") limestone. Only a single dry hole was drilled in this little field, and the reasons why no effort was made to extend the producing area and why the lease was surrendered are not evident. It appears fairly certain that "offsets" to the old wells will encounter either oil or gas in paying quantity, and the fact that the Fort Scott limestone is the productive bed makes the expense of drilling much less than that of the wells which must be bored to the Bartlesville sand or the "Mississippi lime." Furthermore, it has not been established that the deeper beds will not be productive. One well was drilled through a sand corresponding to the Bartlesville sand of the field in sec. 25, without finding either oil or gas in it, but a single well does not prove that the sands are barren at this place. At least one, and preferably two more, should be drilled before such a statement can possibly be justifiable. The very fact that the deeper sands yield abundantly less than 2 miles away makes it seem doubtful that they will be barren here.

There is strong evidence that a large field will be developed on this anticline. This conclusion is supported by the yield that has already been obtained, by the record of the one deep test which has been drilled on it and which shows abundant sands to act as oil reservoirs at the horizons where productive sands are found in near-by areas, by the productivity of similar folds in the township to the east, and by the presence of a great gathering ground to the west from which the oil may migrate for miles up a steep and uniform slope. Further support is found in a test well which was drilled near the axis of the anticline in the extreme northeast corner of sec 13. This well, which is shown as a dry hole on most of the oil maps of this region, is at present making some gas, and the ground around it shows that it also gave a very strong showing of oil. In fact, the indications are so favorable that an "offset" well would be justified.

This anticline should be very thoroughly tested. The failure of one or more tests will in no wise condemn it, for to judge from the township to the east it is to be expected that the sand conditions here are important and may in places neutralize the effect of the structure. Good locations for testing are listed below:

Center of SE. ¼ NE. ¼ sec. 13.
Center of NW. ¼ NW. ¼ sec. 13.
Center of NW. ¼ SE. ¼ sec. 14.
Center of SW. ¼ SE. ¼ sec. 14.
Center of SE. ¼ NW. ¼ sec. 23.
Center of SE. ¼ SW. ¼ sec. 23.

These tests to be adequate should be drilled at least 300 feet below the top of the "Mississippi lime"—that is, to a depth of at least 2,000 feet, and in some of the locations 2,200 feet. In this distance there are at least seven sands which have a chance to be productive and two beds—the Fort Scott limestone and the Bartlesville sand—which have yielded large quantities of oil and gas in this immediate region.

NELAGONEY ANTICLINE.

The Nelagoney anticline is a small pitching fold whose axis runs almost due west from the middle of sec. 28 to the middle of sec. 29. (See fig. 16 and Pl. X.) Structurally it is really more of a terrace than an anticline or dome, as there is but a single closed contour on it, and this one encircles so small an area that it is not significant. The fold shows moderate dips to the west, gentle dips to the north, very gentle dips to the south, and almost no dip to the east. (See contour map, Pl. X.) In fact, it would not be considered a particularly favorable place for oil and gas accumulation were it not the only anticline in a wide area, a fact which gives it an excellent chance to entrap a part of the petroleum that has migrated up the dip from broad gathering grounds to the north, west, and south. That it has succeeded in arresting a part of this oil has been demonstrated by several oil wells which were drilled many years ago near the center of sec. 29. The field formed by these wells lies squarely on the axis of the anticline. The oil comes from the Bartlesville sand. The initial production ranged from 10 to 40 barrels, and the wells were long lived.

The size and shape of this anticline do not encourage the belief that any very large wells will be brought in on it. The present producing field occupies a portion of the fold which is structurally as favorable as any other that might have been chosen for testing. It seems probable that this field may be extended to the north and east, although there is a strong possibility that wells drilled more than 600 feet east of the easternmost of the present producing wells will encounter gas rather than oil. To the south the extension of the pool appears to be limited by a dry hole which was recently drilled, but in spite of this there is a very good chance for small production on a plunging anticlinal nose that occupies the SW. ¼ sec. 29 and may be considered a part of the Nelagoney anticline. A good location for a test in this area would be near the center of the west half of the quarter section.

JAVINE ANTICLINE.

Most of the Javine anticline lies in T. 25 N., R. 11 E., but one lobe of it extends into T. 25 N., R. 10 E. The axis of this lobe enters sec. 25 near the southeast corner and extends northward almost to the north line of the section. (See Pl. X.) This fold may be expected to influence oil and gas accumulation throughout the E. ½ and on a part of the NW. ¼ sec. 25.

The productivity of this fold has been established by nine oil wells and three gas wells in T. 25 N., R. 10 E., and by many wells in T. 25 N., R. 11 E. These wells obtain oil from the Bartlesville sand and had initial yields of 10 to 70 barrels a day. The gas wells came in at 4,000,000 to 9,000,000 cubic feet a day and obtain gas from the same sand as that yielding the oil in the oil wells. None of the wells have been bored deep enough to ascertain whether or not oil and gas bearing sands in the "Mississippi lime" underlie this field. However, they are known to be present at other localities in the Osage Reservation, and it should be assumed that they are present here until deep drilling has justified or disproved the assumption.

This anticline should be developed by extending the oil field which already exists. It can probably be extended both to the north and to the west, although it is probable that the average initial production of the wells drilled west of the present field will be considerably smaller than the average of those which have been drilled to date. The shape of the anticline suggests that in the NE. ¼ NW. ¼ sec. 25 oil may be obtained from some of the sands above the Bartlesville sand, as there is here a structural terrace much like that on which the small field in secs. 14 and 23 is developed. This part of the anticline should be drilled even though attempted extension of the field in the SE. ¼ sec. 25 should result in dry holes.

At least one well should be bored on the Javine anticline to a horizon 300 feet or more below the bottom of any of the existing wells in sec. 25. A good location for this deep well is in the NE. ¼ SE. ¼ sec. 25. A fair location would be about 300 feet north and 900 feet west from the southeast corner of the section. The well should not be drilled farther west than this. Deep drilling far down on the flanks of anticlines is rarely justifiable unless other wells better located have already demonstrated the possible presence of deep-lying oil sands.

QUAPAW ANTICLINE.

The Quapaw anticline is an inconspicuous fold whose axis trends northwestward through the SW. ¼ sec. 36 and across the southern part of sec. 35. There is no closure, and the dips in all directions are gentle. The structure is not well adapted to effect an accumulation of oil or gas, and it is not in the least surprising that wells drilled near the axis of the fold in the SE. ¼ sec. 35 and in the SW. ¼ sec. 36 should have failed to find commercial amounts of oil or gas.

NORTH COCHAHEE DOME.

The North Cochahee dome is a small but well-defined uplift whose crown lies in the SW. ¼ sec. 31. The closure is about 20 feet. The rocks on the flanks of the dome dip fairly steeply in all directions from the crown. The dips to the north are particularly well defined, but the dips to the south are small both in degree and in vertical extent. The territory which seems to be distinctly a part of this dome as distinguished from the general regional structure includes the W. ½ sec. 31, T. 25 N., R. 10 E., and parts of sec. 36, T. 25 N., R. 9 E., sec. 1, T. 24 N., R. 9 E., and sec. 6, T. 24 N., R. 10 E.

Five wells, all excellently located with respect to the structure, have been drilled on this dome, and all have found large volumes of gas with showings of oil. Farther south, in sec. 6, T. 24 N., R. 10 E., wells on a similar dome, which is separated from the North Cochahee dome by a shallow saddle, have had initial yields of 25 to 350 barrels a day. The wells on the North Cochahee dome in sec. 31 are located a little east of the center of the crown of the dome, but a gas well on this dome in the SE. ¼ sec. 36, T. 25 N., R. 9 E., is considerably west of the axis.

It appears probable that a large part of this dome is occupied by gas and will not yield oil, but oil will probably be found well down on the west, northwest, southwest, and southeast flanks. It seems likely that the oil field which has been developed in the western portions of secs. 25 and 36, T. 25 N., R. 9 E., may be extended to the east and join with the gas field in sec. 31, T. 25 N., R. 10 E., and in the SE. ¼ sec. 36, T. 25 N., R. 9 E.

Gas was found on this dome in many sands, but the strongest flows came from sands which were believed by the drillers to be the Bartlesville and beds in the "Mississippi lime." The deepest pro-

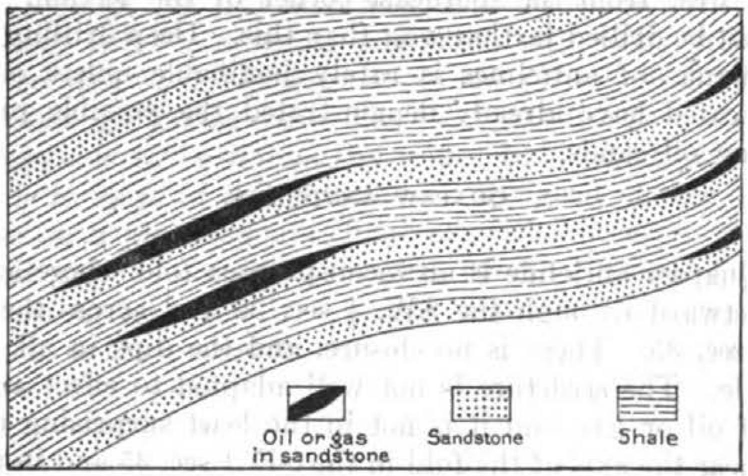


FIGURE 17.—Cross section illustrating flexing of beds in terrace structure and theoretical position of oil pool on terrace.

ducing gas sand is about 300 feet below the top of the "Mississippi lime." The oil wells in sec. 6, T. 24 N., R. 10 E., and secs. 25 and 36, T. 25 N., R. 9 E., obtain their oil from the Bartlesville (?) sand. In secs. 25 and 36 some oil and gas are also obtained from the Fort Scott ("Oswego") limestone.

A good location for a test well on that part of the dome which is in T. 25 N., R. 10 E., is near the southwest corner of the NW. ¼ sec. 31. An alternative location is the southwest corner of the NW. ¼ NW. ¼ sec. 31.

SWAIN TERRACE.

In the SW. ¼ sec. 15 and the NW. ¼ sec. 22 there is an area of terrace-like structure where the rocks dip very gently westward for some distance and then plunge sharply in the same direction, giving a cross section like that shown in figure 17. This terrace may have caused oil or gas to accumulate. Similar terraces elsewhere in Osage County have yielded oil, particularly from the sands above the

Bartlesville. Accordingly it seems that this flexure is worthy of a test. A good location for the test is about 300 feet north and 600 feet west of the southeast corner of sec. 16. In this area drilling below the Bartlesville sand, which should be found at about 1,850 feet, is not recommended.

UNFAVORABLE AREAS.

The structure over much of T. 25 N., R. 10 E., seems to be unsuited to bring about appreciable accumulations of oil or gas. This does not necessarily mean that pools of oil or gas do not exist under the unpromising areas, as favorable conditions in the oil sands may entirely counterbalance the unfavorable effects of the attitude of the beds; but unless these areas are invaded by the extension of pools opened on territory which is structurally more favorable it should not be prospected without due recognition of the risks. The probabilities are very great that such prospecting will result either in total failures or in wells of such small productivity that the cost of drilling will never be repaid. This is shown by the wildcat drilling which has already been done in this township. Of the nine holes known to have been bored outside of any area of anticlinal structure, not a single one showed sufficient oil or gas to justify an attempt at production.

Areas where the structure is unfavorable include the S. ½ sec. 1, all of sec. 2, the N. ½ sec. 3, the N. ½ sec. 4, the E. ½ sec. 6, the SW. ¼ sec. 7, all but the SE. ¼ sec. 11, the N. ½ sec. 12, the W. ½ sec. 16, secs. 17, 18, and 19, the W. ½ sec. 21, the W. ½ sec. 27, the E. ½ sec. 28, all but the SE. ¼ sec. 30, sec. 32, and the W. ½ sec. 33.

The fact that these lands are listed as structurally unfavorable must not be taken to indicate that the rest of the township is structurally favorable. Much of the area not listed above certainly can not be regarded as structurally favorable, but at the same time its structure is not of such a type as to preclude absolutely the possibility of success.

T. 25 N., RS. 11 AND 12 E.

By Oliver B. Hopkins.

INTRODUCTION.

The area included within T. 25 N., Rs. 11 and 12 E., lies in the eastern part of the Osage Reservation, southwest of Bartlesville and northeast of Bigheart. (See fig. 1.) There are no towns within the area; the only settlements consist of oil camps and a few small ranches. Bartlesville is the largest town near these townships and the town from which they are most accessible.

Field work on these townships was done between the first of April and the middle of June, 1918, by W. A. English, K. C. Heald, and the writer, assisted by W. G. Gulley, R. L. Triplett, and H. J. Weeth, respectively, as instrument men. The relative areas covered by the three parties are shown on the diagram inserted on Plate XI. The mapping was done entirely by plane table, in part by stadia traverses and in part by triangulation.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL CHARACTER.

The exposed rocks in the area are of middle Pennsylvanian age and comprise about 430 feet of alternating beds of shales and sandstones with thin beds of limestones. The general character and thickness of the beds are shown in figure 18. A complete description of the stratigraphy will not be given here; only the most prominent beds or key rocks which were used in mapping the structure will be described.

The lower 180 feet of beds exposed in these townships consists dominantly of shale but contains two prominent sandstones and three thin limestones. All three limestones are found at places along the east side of T. 25 N., R. 12 E., and the upper two are found in the valley of Candy Creek in the southwestern part of the same township. The two lower limestones are well exposed in the road leading up the escarpment near the middle of the east line of sec. 21, T. 25 N., R. 12 E. The lowest limestone in the section is the same as that found in the northern part of T. 23 N., Rs. 11 and 12 E., and described as "*Fusulina*-bearing gray limestone." The most conspicuous beds in the upper 250 feet of exposed rocks are described below. The position of these beds in the section of exposed rocks is shown in figure 18, and their position in relation to the productive formations on Plate XII.

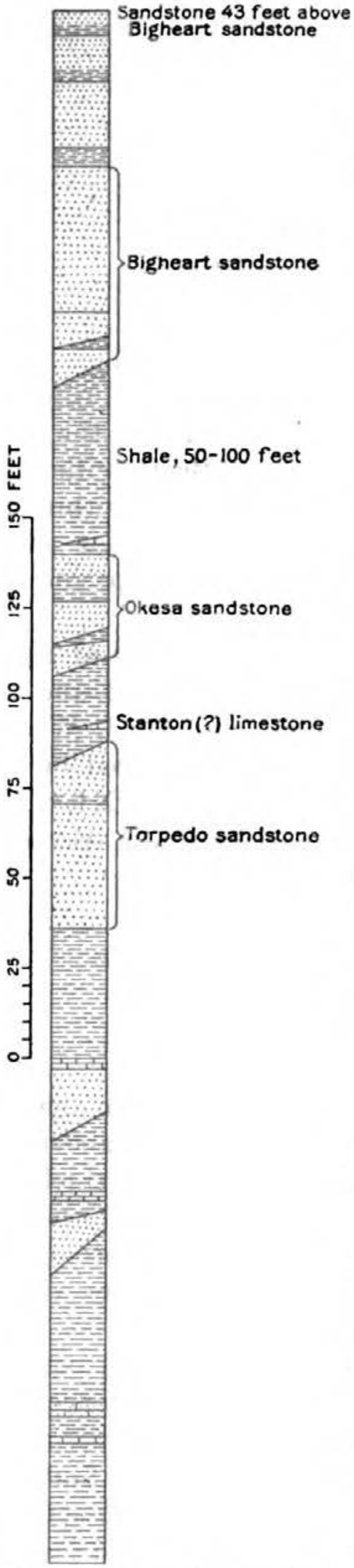


FIGURE 18.—Section showing succession of beds exposed in T. 25 N., Rs. 11 and 12 E.

KEY BEDS.

Torpedo sandstone.—The lowest bench of massive cliff-making sandstone about 75 feet above the valley floor at Torpedo is here named the Torpedo sandstone. This sandstone forms the top member of the division described by Shannon and Trout [1] as the Wilson formation. It rims the valley of Sand Creek and is typically exposed 1 mile northwest of Torpedo, on the north side of the creek. Here it consists of about 30 feet of massive medium-grained sandstone which breaks into large ripple-marked blocks. It is immediately underlain by shale and overlain by a bed of hard gray limestone 2 to 3 feet thick, which is loaded with crinoid stems and weathers cinnamon-brown.

This sandstone ranges from 30 to 60 feet in thickness in T. 25 N., R. 12 E., where it is exposed in the valleys along the north township line. It forms the resistant bed near the top of the prominent escarpment along the east side of the township and rims the valley of Candy Creek and its tributaries in the southern part. This sandstone crops out, as shown on Plate XI, in two prominent benches in the northern part of T. 25 N., R. 12 E., but in the southern part the upper bench either merges into the lower or gives place to shale, as only the lower bench is conspicuous there. The lower bench generally forms a nearly vertical cliff,

[1] Shannon, C. W., and Trout, L. E., Petroleum and natural gas in Oklahoma: Oklahoma Geol. Survey Bull. 19, p. 89, 1915.

whereas the upper bench, though somewhat softer and weathering more readily, usually shows a fairly well defined contact with the overlying shale. The thin limestone that overlies this sandstone near Torpedo is present in the northern part of T. 25 N., R. 12 E., but disappears farther north. The writer believes that this limestone may be the Stanton limestone of Kansas and that it is 15 to 20 feet above the horizon of the Birch Creek limestone in T. 24 N., Rs. 10 and 11 E. The Torpedo sandstone, with the overlying limestone, is well exposed in the SW. ¼ SE. ¼ sec. 4, T. 25 N., R. 12 E.

Okesa sandstone.—The Okesa sandstone was named by Clark from its exposure near Okesa.[1] It was traced in a conspicuous outcrop halfway across the east side of T. 25 N., R. 11 E., and around the floors of the two principal stream valleys in that township. (See Pl. XI.) In the northern part of T. 25 N., Rs. 11 and 12 E., the Okesa sandstone comprises three prominent sandstone beds separated by thin beds of shale and has an aggregate thickness of about 30 feet. Here it is overlain by red clay shale and in places a thin limestone occurs 7 feet above it. The middle bed was traced in the northern part of these townships. (See Pl. XI.) The Okesa sandstone increases in thickness toward the south, so that on the line between Tps. 25 and 24 N., R. 11 E., it replaces most of the underlying shale and locally rests on the Torpedo sandstone. In the southern part of the townships here described the top of the Okesa sandstone appears as a pronounced bench (see Pl. XI), above which is a 50 to 75 foot bed of shale, forming an open belt of country. The top bed of the Okesa sandstone in this area is a massive to thin, even-bedded sandstone whose upper surface is covered with impressions of fossil pelecypod shells. A thin limestone occurs in places 5 feet above this sandstone, as exposed near the center of sec. 35, T. 25 N., R. 11 E., and in the same area a massive bench of sandstone with a rough, lumpy top surface fringed by trees is exposed 20 feet below it.

Bigheart sandstone.—The name Bigheart sandstone was given by Snider[2] to a series of sandstones [and shales] 175 feet thick exposed in the hills west of the town of Bigheart. In the present report the name is restricted to beds of sandstone 57 to 70 feet thick resting on the same shale as at Bigheart. Thus applied, the Bigheart includes a series of rough massive lenticular sandstones which generally form two prominent benches. It is underlain by 50 to 100 feet of gray shale, which is locally red in its upper 6 feet, and overlain by a thin bed of shale which separates it from the thinner, more slabby sandstones

[1] Clark, F. R., report on T. 26 N., R. 11 E.: U. S. Geol. Survey Bull. 686–I, 1918.

[2] Snider, L. C., Preliminary report on the clays and clay industry of Oklahoma: Oklahoma Geol. Survey Bull. 7, p. 221, 1911.

above. In the eastern part of T. 25 N., R. 11 E., the base of the sandstone was traced (see Pl. XI); in the southwestern part the top of the first bench, from 10 to 26 feet above the base, was traced; and in the northwest corner of the township the top of the sandstone, which is marked by a rough, knotty surface, was traced. The top of this sandstone is well exposed along the road south of the middle of the north line of sec. 21, T. 25 N., R. 11 E.

Sandstone 43 feet above Bigheart sandstone.—The sandstone outcrop in the northwest corner of T. 25 N., R. 11 E. (see Pl. XI), is a rough, blocky bed 43 feet above the top of the Bigheart sandstone. This sandstone is in places a prominent ledge, which is not traceable far beyond the limits of that township.

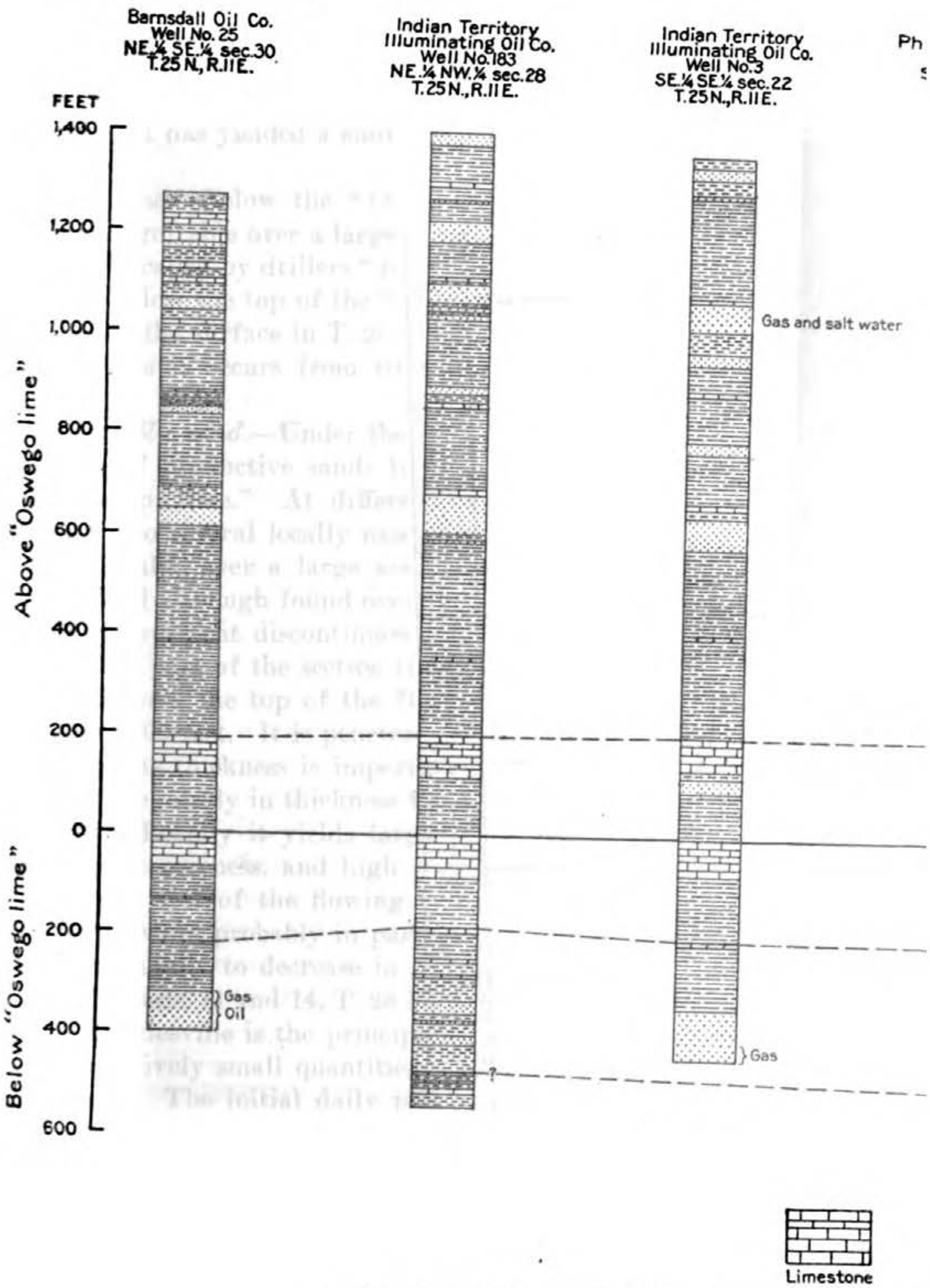
ROCKS NOT EXPOSED.

The Pennsylvanian rocks not exposed in this area are known from their outcrops to the east and from well logs. Plate XII shows in graphic form six typical well logs arranged in general along an east-west line across T. 25 N., Rs. 11 and 12 E., and a generalized section showing the exposed rocks and the most noteworthy unexposed rocks.

Big lime.—The first generally recognized bed encountered in the wells is the Big lime, which is found at depths ranging from 900 feet below the surface on the east side of this area to 1,200 feet on the west side. This is the shallowest productive formation within the area; it yields gas in small quantities—1,000,000 to 2,000,000 cubic feet a day in a number of widely separated wells—but so far as known does not yield oil in this area. It has an average thickness of about 77 feet.

Peru sand.—The Peru sand is generally separated from the Big lime by 20 to 25 feet of shale and is encountered in the wells at depths of 1,000 to 1,300 feet. In these townships this sand is productive of oil in only two wells, so far as known, both in the NE. ¼ sec. 4, T. 25 N., R. 12 E., in which the initial daily production was 1 to 2 barrels. This sand appears to have a maximum thickness of 50 feet and to extend over a considerable area. Under favorable structural and sand conditions it would be expected to yield small quantities of oil.

"*Oswego lime.*"—The "Oswego lime" is about 200 feet below the top of the Big lime, or from 1,100 to 1,400 feet below the surface in this area. It has an average thickness of about 73 feet and is one of the important subsurface key beds in the region. It yields 2,500,000 to 5,000,000 cubic feet of gas a day in wells in the western part of T. 25 N., R. 12 E., and the eastern part of T. 25 N., R. 11 E. The gas is believed to come from the porous dolomitized limestone.



SECTIONS SHOWING TYPICAL WELL LOGS IN T. 25 N., Rs.

Squirrel sand.—The Squirrel sand is the next productive formation below the "Oswego lime" and is usually separated from it by 10 feet or more of shale. This sand is recognized in many of the wells over the entire area and has a thickness of 10 to 40 feet. So far as known, oil is not obtained from the sand in this area, but at least three wells in secs. 4 and 20, T. 25 N., R. 12 E., obtain gas from it. It has yielded a show of oil and much salt water in many wells.

Pink lime.—Below the "Oswego lime" the next bed, which is easily recognizable over a large area, is a hard limestone, from 5 to 8 feet thick, called by drillers "pink lime." It is found approximately 200 feet below the top of the "Oswego lime," or from 1,300 to 1,600 feet below the surface in T. 25 N., Rs. 11 and 12 E. It is a valuable key bed, as it occurs from 100 to 125 feet above the Bartlesville sand.

Bartlesville sand.—Under the name Bartlesville sand are included a group of productive sands lying between the pink lime and the "Mississippi lime." At different places the Bartlesville has been divided into several locally named sands, but these subdivisions are not applicable over a large area, as the sands are essentially lenticular, and although found over a wide area at about the same horizon they represent discontinuous sand bodies. They probably represent that part of the section that is of Pottsville age.

In this area the top of the Bartlesville is reached at a depth of 1,400 to 1,800 feet. It is penetrated in relatively few wells, and consequently its thickness is imperfectly known; it is found, however, to vary irregularly in thickness from 30 feet to a maximum of about 120 feet. Locally it yields large flows, presumably because of its thickness, coarseness, and high porosity, but "offset" wells within 500 or 600 feet of the flowing wells may prove to be only small pumpers, owing probably in part to decrease in the thickness of the sand but mainly to decrease in porosity. Such local variations are marked in secs. 11 and 14, T. 25 N., R. 11 E.

The Bartlesville is the principal productive sand in this area. It yields relatively small quantities of oil, but the wells are generally long lived. The initial daily production of 133 wells in T. 25 N., R. 11 E., was 14,638 barrels, or an average of 110 barrels. Most of the wells producing from the Bartlesville range in initial production from 50 to 150 barrels.

"*Mississippi lime.*"—The Bartlesville sand is usually separated by 25 to 50 feet of shale from the underlying limestone, commonly called the "Mississippi lime." The age of this limestone is not definitely determined, but it is believed to be the equivalent of the Boone limestone of northeastern Oklahoma, as shown in Plate XII.

It has yielded gas in a number of scattered wells in the area but, so far as known, only showings of oil. However, no well should be abandoned as dry until it has tested for oil and gas the upper 300 feet of this limestone, the top of which is reached at depths of 1,500 to 1,900 feet in this area.

STRUCTURAL FEATURES.

The general structure of this area conforms to that of the region as a whole and shows the normal west dip, averaging 40 feet to the mile, interrupted here and there by numerous relatively small folds, as shown on Plate XI. The structure contours on this plate are based on a theoretical datum approximately 200 feet above the top of the Torpedo sandstone. Slight convergences between this sandstone and a lower limestone, which make this interval vary somewhat, are taken into account. Between the Torpedo sandstone and the Bigheart sandstone there is a variation in interval amounting to approximately 50 feet, which was also taken into account and which prevents the structure as shown from conforming exactly with that derived from the local contouring on the basis of the upper beds. The position of the contours shown in Plate XI by broken lines is in doubt, owing to insufficiency of rock outcrops.

The contours on the maps in this report match exactly those for the townships to the south and west, where the same beds were used as key rocks. The contours along the north edge of T. 25 N., R. 11 E., do not tie with those for the adjoining township to the north, because in general higher beds were used for contouring in the southern township than in the northern one and the lenticular character of the beds made it impossible to tie the key rocks together so that the convergences could be correctly taken into account. Along the line between Tps. 25 and 26 N., R. 12 E., the contours tie up fairly closely, and when the work in the northern township is completed they may be found to match exactly, because the same general series of beds was used in both townships.

AREAS OF FAVORABLE STRUCTURE.

T. 25 N., R. 12 E.

In T. 25 N., R. 12 E., there are four well-developed anticlines—the Farrell, Perrier, Zola, and Forty-seven—and parts of two others, the west flank of the County Line anticline and the south flank of an unnamed one which extends into sec. 4. (See fig. 19 and Pl. XI.)

County Line anticline.—The County Line anticline, so named from its position along the Washington-Osage county line, in secs. 15, 22, and 27, has not been outlined in its entirety, as the mapping was not carried beyond the limits of Osage County. This anticline is separated by a low saddle from the Farrell anticline to the west, and has its crest along the county line in secs. 22 and 27. A large pool

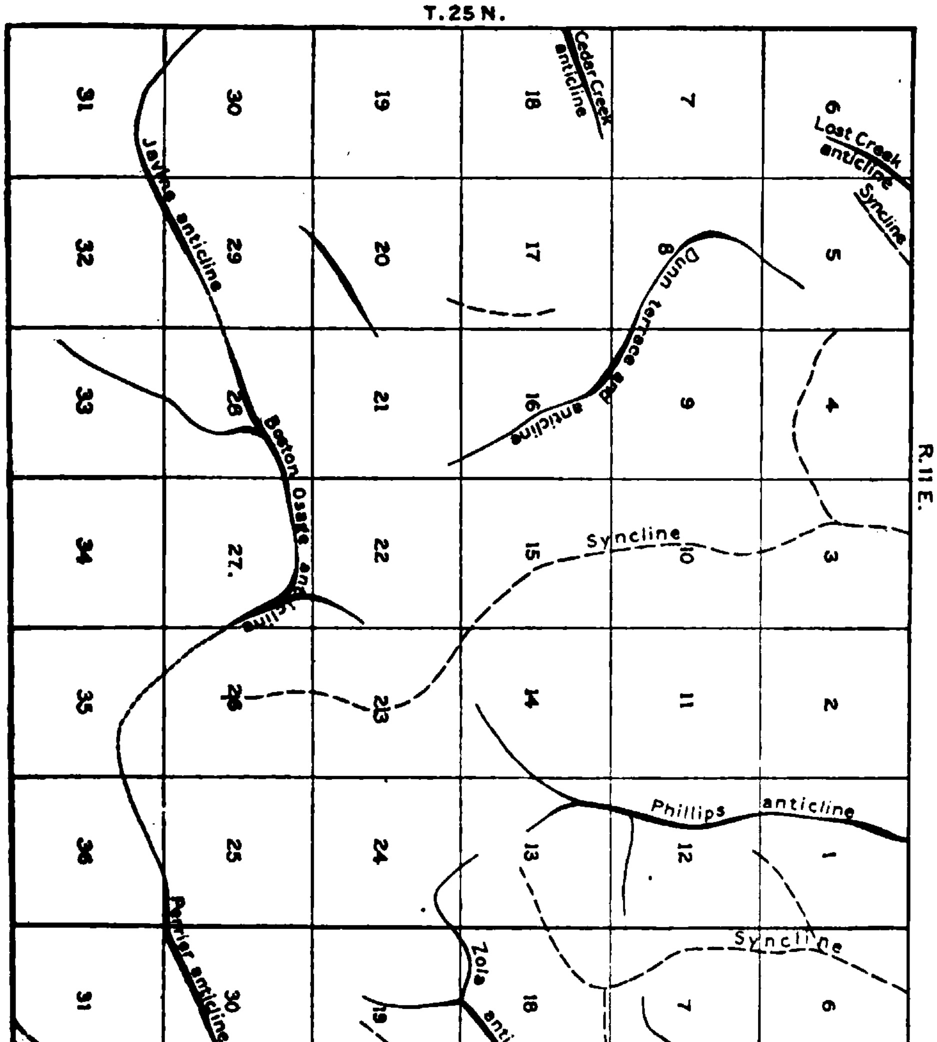


FIGURE 19.—Sketch map showing location of axes of anticlines and synclines in T. 25 N., Rs. 11 and 12 E.

of oil has already been developed on it, as shown on Plate XI, extending down on its western flank almost to the saddle referred to above. The limits of this pool are gradually being extended, especially to the southwest. To judge by the structure, the pool is more likely to be considerably extended to the south, in secs. 22, 27, and 28, than in any other direction. Continued drilling away from the proved area as long as profitable wells can be completed is the accepted way of finding the limits of the pool. Except one small well in the SW. ¼ sec. 22, which probably derives its oil from the Peru sand, all the wells in this pool obtain oil from the Bartlesville, which consists here of two separate sands from 30 to 40 feet apart. According to the driller, the Bartlesville thins near the south end of the pool, as now developed, and thickens to the north. Few if any well-located tests have reached the "Mississippi lime" on this anticline, and no wells have completely tested it. A deep well near the center of sec. 22 would be justified to test this lime. Its depth can not be accurately forecast, as no reliable logs are available for this area, but it lies approximately 1,450 to 1,500 feet below the surface.

Farrell anticline.—The Farrell anticline, so named from the allottees who hold much of the land on it, lies mainly in sec. 20 but extends into secs. 16, 17, 21, and 29, covering an area of about two sections. The crest of the anticline extends northeastward across the southeast corner of sec. 20 and northward along the east side of the section to a point near the middle of the line between secs. 16 and 17, where it plunges to the north. The crown or high part of this anticline is outlined by the 1,150-foot contour, which is the lowest closed contour; it has a reversal of 40 feet and an area of closure of about 300 acres. This anticline is separated by low saddles from the County Line anticline on the east and the Perrier anticline on the southwest. On its northwest side the beds dip steeply to a shallow syncline which separates it from the Zola anticline.

The Farrell anticline has been extensively tested for gas, which is found in the "Oswego lime," Big lime, Squirrel and Bartlesville sands, and "Mississippi lime." So far as known only three dry holes have been drilled on this anticline. One well in the NW. ¼ NE. ¼ sec. 17 was dry in the Bartlesville sand at a depth of 1,812 feet; another in the NW. ¼ NW. ¼ sec. 21 was dry after having penetrated 21 feet into the "Mississippi lime" at a depth of 1,866 feet; the third, of which no record is available, is in the NW. ¼ NE. ¼ sec. 29. The records of all the wells that have reached the Bartlesville on this anticline indicate a thickness of 70 to more than 100 feet. No oil has yet been found on this anticline, except possibly in a well in the SW. ¼ NW. ¼ sec. 21, which is shown as an abandoned well on the accompanying map. There is no reason why oil should not be found, as the structure and sand conditions are favorable. A favorable place for a test is near the center of the SE. ¼ SW. ¼ sec. 20. The depth to which a well will have to penetrate to reach the different formations, allowance being made for differences in elevation and dip and in the rocks that will be encountered, is shown by the log of the Union Oil Co.'s well No. 49 on Plate XII.

Perrier anticline.—The Perrier anticline lies in secs. 30 and 31, T. 25 N., R. 12 E., and secs. 25 and 36, T. 25 N., R. 11 E. The anticline is bordered on the east by a broad, shallow syncline, whose axis follows the line between secs. 31 and 32 and has a blunt ending in sec. 29, T. 25 N., R. 12 E.; on the north it is separated by an equally broad, shallow syncline from the Zola anticline. To the northeast the Perrier anticline is connected by a low saddle with the Farrell anticline, and to the west a nose of the Perrier anticline may be considered to connect it with the Boston-Osage anticline. The crown or high part of this anticline is in secs. 30 and 31, T. 25 N., R. 12 E., and is outlined by four closed contours, the 1,120 to 1,150 foot contours, forming an inclosed area of approximately 400 acres. From this crown a nose leads off to the west and a smaller and less conspicuous one to the southwest.

Six wells have been drilled on this anticline—one gas well and two oil wells, all now abandoned, and three dry holes. The abandoned gas well in the SW. ¼ NW. ¼ sec. 31, T. 25 N., R. 12 E., found gas in the Bartlesville at 1,649 to 1,696 feet and water at 1,696 to 1,810 feet, the bottom of the well. The logs of the three other wells in this section are not available. The abandoned well in the NW. ¼ NE. ¼ sec. 36, T. 25 N., R. 11 E., had an initial daily production, before being shot, of 5 barrels of oil and 1,000,000 cubic feet of gas from the Bartlesville sand. The Bartlesville was reached at 1,638 feet and extended down to 1,780 feet. The log records gas and water in the "Oswego lime" and gas, a show of oil, and water in the Peru sand, which is 50 feet thick and was encountered at 1,170 to 1,220 feet. The well in the NE. ¼ NE. ¼ of the same section was reported as dry, although its log showed sand from 1,657 to 1,780 and from 1,784 to 1,799 feet, with gas and oil in the upper part. It seems likely that this well might have been successful had it not been drilled so deep into the sand, to a level where it was saturated with water.

Favorable structure, a thick sand, and a good gathering ground indicate that this anticline should be productive. Two wells have been drilled in the NW. ¼ NW. ¼ sec. 31, T. 25 N., R. 12 E., but the records of these wells are not available, and it is not known how deep they were drilled. So far no test has been made of the highest part of the fold, which is in the SW. ¼ sec. 30. It is almost certain that gas can be developed in paying quantities in that quarter section, and it is highly probable that oil can be obtained on the flanks of this anticline in paying quantities over a considerable area. Besides the Bartlesville, the Peru sand, the "Oswego lime," and the upper 300 feet of the "Mississippi lime" should be fully tested. A favorable locality for a deep test would be on the crest of the fold near the center of the SW. ¼ sec. 30. The depth to the different formations varies considerably with the locality, but the approximate depths will be as follows: "Oswego," 1,325 feet; Bartlesville, 1,650 feet; "Mississippi lime," 1,850 feet.

Zola anticline.—The Zola anticline, so named from the Zola Oil Co., which holds leases on most of it, lies 2 miles north of the Perrier anticline, mainly in secs. 17, 18, and 19, T. 25 N., R. 12 E., but extends into the SE. ¼ sec. 13 and the NE. ¼ sec. 24, T. 25 N., R. 11 E. This anticline has unusually steep dips on its north and northwest flank and gentle dips on its east, south, and southwest flank. It is bounded on the northwest and southeast by synclines which separate it from the Phillips and Farrell anticlines. The lowest closed contour is the 1,090-foot and the highest is the 1,120-foot, giving a closure of 30 to 40 feet and an area of closure of approximately one section, or 640 acres. This area of closure is in the southeastern part of sec. 18, the southwestern part of sec. 17, and the northern part of sec. 19.

This anticline is entirely untested; the nearest wells are two dry holes in the syncline three-quarters of a mile southeast of the crest of this fold. Structurally this anticline is favorable for oil and gas accumulation, and though nothing is known of the local conditions of the sands, it may be inferred from the conditions on the Farrell anticline, a mile to a mile and a half to the east, that they would be favorable here. It would be reasonable to look for gas in the Big lime, "Oswego lime," Bartlesville sand, and "Mississippi lime" and for oil in the Bartlesville. A favorable place to test this anticline for gas would be near the center of the SE. ¼ sec. 18, and for oil in the SW. ¼ SW. ¼ of the same section, T. 25 N., R. 12 E., or in the NW. ¼ NE. ¼ sec. 24, T. 25 N., R. 11 E. Near the crest of this fold and in the bed of Candy Creek the top of the Big lime may be expected at about 925 feet and the other formations at depths below corresponding to the intervals shown on Plate XII.

Forty-seven anticline.—The Forty-seven anticline, so named from its position near the center of lot 47, is mainly in secs. 5 and 8 but extends into adjacent sections. It is bounded on the east by a closed synclinal depression; it is connected on the south by a saddle with the Farrell anticline, on the west-southwest by a long, projecting nose and saddle with the Phillips anticline, and on the northeast by another saddle with the unnamed anticline which extends into sec. 4. The lowest closed contour is the 1,090-foot and the highest one is the 1,120 foot, giving a closure of 30 to 40 feet and an area of closure of about one-third of a section, or 200 acres. The highest part of the anticline is largely in the NE. ¼ sec. 8 but extends into the edge of the adjoining sections on the north and east. The anticline is roughly triangular in outline, the three points of the triangle being represented by the three noses which are connected by low saddles with the three anticlines mentioned above. The nose extending to the southwest is broad and flat, possessing a form resembling somewhat a terrace, as shown in the W. ½ sec. 8 and the E. ½ sec. 7.

Oil has been obtained in large quantities on the north and northwest sides of this fold, and the productive area is almost continuous across the saddle which connects it with the anticline to the northeast. The oil comes exclusively from the Bartlesville sand, and the initial daily yield of the wells is usually from 20 to 30 barrels. The Peru sand is reported to be about 40 feet thick here, but so far has been found to be unproductive. From a consideration of the structure the most likely region where an extension of the pool will be found is in the NE. ¼ and the E. ½ NW. ¼ sec. 5 and in the N. ½ sec. 8. So far as known, the wells on this anticline have not reached the "Mississippi lime," which will probably be productive of gas. A good location for a test well in the "Mississippi lime" would be in the NW. ¼ NE. ¼ NE. ¼ sec. 8. At this locality the depth to the "Mississippi lime" is approximately 1,850 feet.

T. 25 N., R. 11 E.

General features.—The dominant structural features of T. 25 N., R. 11 E., consist of a belt from 1 to 2 miles wide, crossing the township diagonally from sec. 2 to sec. 30, in which the dip is strong to the northwest, and areas of more gentle dips with gentle folds on both sides of this belt. (See Pl. XI and fig. 19.) The eastern margin of this belt of strong northwest dips is believed to afford exceptionally favorable structural conditions for the accumulation of oil and gas, especially where anticlines occur.

In this township the Bartlesville sand varies widely in thickness and porosity, causing the initial production of wells to vary markedly from place to place. In the northeastern part of the township, on what is subsequently described as the Phillips anticline, the sand varies irregularly in porosity, and consequently the wells have a wide range in initial production. In the southwestern part of the township the sand conditions are particularly favorable in a belt stretching from a point near the southwest corner of sec. 30 to the southeast corner of sec. 16, in which the initial production of the wells ranges from 100 to 1,000 barrels a day. The particularly favorable character of the sand in this belt probably accounts for the occurrence of oil in the synclinal depression in the SE. ¼ sec. 17, which would be expected from structural considerations to be barren of oil. It is not certain, however, that this minor syncline in the surface rocks is repeated in the Bartlesville sand.

Only one fault of considerable extent, which may affect the deeply buried rocks, has been found, but there are a number of small faults which are believed to affect only the surface rocks. A conspicuous small local fault, which is not traceable more than a quarter of a mile, occurs in the SW. ¼ SW. ¼ sec. 14. It strikes almost due east and has a downthrow of about 35 feet on the south side. The largest fault found in this township is in sec. 34, and although it is difficult to trace, it is believed to be about a mile long. It trends N. 20° W. and has a downthrow on the northeast side, amounting to about 60 feet near its middle.

Phillips anticline.—The Phillips anticline, so named from the Phillips Petroleum Co., which has a large camp on it, is an elongated fold extending from sec. 13 almost due north through secs. 12 and 1 into sec. 36 of the adjoining township. The 1,050-foot contour is the lowest closed contour, and the area of closure is about one and a half sections. There are two crowns or domes on this anticline, one at the north end, in the N. ½ sec. 1, which may be appropriately called the North Phillips dome; and another near its south end, in the SW. ¼ sec. 12 and the NW. ¼ sec. 13, which may be called the South Phillips dome. The North Phillips dome, which is outlined by the 1,060 and 1,070 foot closed contours, shows steep dips to the west, north (in the adjoining township), and east; to the south it is connected by a low, narrow, closely folded saddle with the South Phillips dome. The South Phillips dome is also outlined by the 1,060 and 1,070 foot closed contours and shows a strong dip to the west and gentle dips to the north, east, and south.

The known limits of the oil and gas pool on this anticline are now being rapidly extended. Gas has been found on the crowns at the two ends of the anticline, and oil on its west flank. Gas will probably be obtained in large amounts in a large part of the area surrounded by the 1,050-foot contour, especially in the S. ½ sec. 12, the NW. ¼ sec. 13, and the E. ½ NW. ¼ and the W. ½ NE. ¼ sec. 1. The oil pool will probably be found to extend to the north over the W. ½ W. ½ sec. 1, the E. ½ E. ½ sec. 2, the E. ½ sec. 11, the greater part of sec. 12 except the NE. ¼, the E. ½ sec. 14, and the NW. ¼ sec. 13.

Oil in this pool is produced exclusively from the Bartlesville sand. The wells here range in initial production from a fraction of a barrel to 1,000 barrels a day, but most of them produce from 10 to 100 barrels. There is a wide variation in the production of wells only 500 to 600 feet apart. This variation, which is believed to be due to local sand conditions, is marked in the NE. ¼ sec. 14, where there are a 1,000-barrel well and a 10-barrel well 500 feet apart. In an area where the sand shows so wide a variation in thickness or porosity, or both, a dry hole should not be considered to condemn even a quarter section, provided it is in an area of favorable structure.

Although it is likely that a number of small wells and dry holes will be drilled in the area outlined above as probably productive, it is believed that oil will eventually be obtained in much of the area. As the long west dip favors drainage to this fold the entire area of favorable structure should be carefully tested. It seems probable that a small quantity of oil may be found in the Peru sand, which is reported to have a thickness of 30 feet or more. Gas has been found here in the "Oswego lime," Bartlesville sand, and "Mississippi lime." So far as known, only one well in this area has penetrated more than 10 or 20 feet into the "Mississippi lime," which is worthy of a deep test. Favorable localities for deep tests are in the SW. ¼ SW. ¼ sec. 12 and near the center of the NW. ¼ sec. 1. The depth to the top of the "Mississippi line" in the first locality is approximately 1,860 feet, and in the other about 75 feet less.

Boston Osage anticline.—The Boston Osage anticline, so named from the oil company that holds leases to a considerable part of it, is in the south-central part of the township, largely in secs. 21, 22, 23, 26, 27, and 28. It is a broad, irregular-shaped anticline with two crowns. It has fairly strong dips on its southwest, west, and northwest flanks and gentle dips on the east into a broad, shallow syncline. On the southeast it is connected by a saddle with a long anticlinal nose which projects from the Perrier anticline. The dips on its south flank are locally increased by a fault which trends N. 20° W. and has a downthrow of about 60 feet on its east side. The eastern crown of this anticline, which lies largely in the NE. ¼ sec. 27, is outlined by the 1,040-foot contour, which incloses approximately 250 acres. The western crown is largely in the NE. ¼ sec. 28 and is outlined by the 1,030-foot contour; it has a reversal of about 20 feet and an area of closure of approximately 140 acres.

The Boston Osage anticline has a number of scattered oil and gas wells on its northern and northwestern flanks. Gas is derived from both the Bartlesville sand and the "Mississippi lime"; oil is derived from the Bartlesville only. The oil wells so far drilled have been small producers, yielding from 10 to 20 barrels daily. The gas in wells on the flanks of the anticline is derived from the "Mississippi lime." The fold is large and well placed with reference to the belt of steep dips. To judge from the area of favorable structure and the scattered oil and gas wells on it the productive area can be considerably extended by further drilling. The chances for extension are particularly good in secs. 21, 22, 27, and 28 and the western part of sec. 23, and possibly in the northern part of sec. 33. It is likely that the Bartlesville sand will yield largely gas on the crowns and oil on the north and northwest flanks of the anticline. Drilling should be continued away from the already productive wells in an effort to ascertain if the pool extends over the area of favorable structure as outlined above. Structurally this area is comparable to that of the Phillips anticline, and if the sand conditions are favorable a pool approaching the one on that anticline may be discovered here.

Javine anticline.—The Javine anticline, so named from the allottees who own much of the land on it, lies in secs. 29, 30, 31, and 32. This anticline has strong dips to the northwest, west, and south; on the east it is separated from the Boston Osage anticline by a shallow, broad saddle. It has a closure on the east of not more than 10 or 20 feet. It is not certain whether the 970-foot contour is closed as indicated on Plate XI; if it is, the area of closure amounts to about 400 acres and lies in the SW. ¼ sec. 29, the SE. ¼ sec. 30, the NE. ¼ sec. 31, and the NW. ¼ sec. 32. From the main part of this anticline a nose leads off toward the northwest into sec. 25 of the adjoining township. The 930-foot contour shows a small area of closure on this nose along the township line.

Oil has been obtained in large amounts on the west flank, and particularly on the northwest flank, of this anticline. The oil pool extends to the northeast beyond the limits of this anticline to the Dunn terrace, to be described later. So far the crest of this anticline has not been drilled; when it is drilled it is likely to prove gas bearing, as the wells highest up on its flank yield large amounts of gas with the oil. The belt in which the wells show the greatest yield, ranging in initial daily production generally from 100 to 200 barrels and exceptionally to as much as 1,000 barrels, trends northeastward from a point near the southwest corner of sec. 30 to the southwest corner of sec. 16. This belt has its maximum width of half a mile near the northeast corner of sec. 30. Both northwest and southeast of this belt the wells diminish in production to 10 barrels or less. The greater productivity of the wells along this belt is believed to be due to the greater porosity and thickness of sand along it.

The extensions of the oil pool on this anticline will most probably be found in the N. ½ sec. 31, the NW. ¼ sec. 32, and probably the greater part of sec. 29 except the SE. ¼. Gas will probably be found over much of the area inclosed by the 970-foot contour. Continued drilling away from the productive area will gradually define the limits of the pool in the most economical way.

Dunn terrace.—The Dunn terrace is a broad, poorly defined area of relatively flat beds, covering the greater part of secs. 8 and 9, the W. ½ secs. 10 and 15, and most of secs. 16, 17, 20, and 21. It is bordered on the east and southeast by an area of relatively steep west and northwest dips; on the west and north it is less clearly defined but is considered to be limited by the 930-foot contour. On the surface of this terrace are two small anticlines and one closed synclinal depression. The larger of the anticlines, in the SW. ¼ sec. 9 and the NW. ¼ sec. 16, is dome shaped and is outlined by the 960-foot contour. It has an area of closure of slightly more than a quarter of a section and a reversal of dip amounting to 20 feet. The other anticline lies largely in the SE. ¼ sec. 20 and has only one closed contour, the 960-foot contour. It has strong dips on its west and northwest sides, but on the east it merges into the terrace and is poorly defined. The synclinal depression is outlined by the 940 and 930 foot closed contours and lies largely in the SE. ¼ sec. 17 but extends over into the sections adjoining on the east and south.

The oil pool on the Javine anticline, described above, extends northeastward to the southern part of the Dunn terrace. Oil has been found in the area of favorable structure and also in the synclinal depression described above. Its presence is probably due to the belt of favorable sand which crosses this area. (See p. 88.) This pool is being actively drilled and extended at this time (August, 1918). Large wells have been drilled in the SW. ¼ and the NE. ¼ sec. 20 and in the SW. ¼ sec. 16; the maximum initial daily production has been 1,000 barrels. To judge from the structure and the present developments, this pool extends over practically the whole of sec. 20 and probably a large part of secs. 21 and 16, the eastern part of sec. 17, and the SW. ¼ sec. 9. This area is along the trend of large producing wells and is believed to offer good prospects for oil production because of favorable sand conditions. Oil may be found on the northwestern edge of the Dunn terrace; a favorable place to test this area would be near the center of the NW. ¼ sec. 8.

Cedar Creek anticline.—Leading to the west from the Dunn terrace is the Cedar Creek anticline, which extends from the N. ½ sec. 18 into the adjoining township, where it is largely developed. In this township this anticline has the form of an anticlinal nose, with its high part trending west through the center of the N. ½ sec. 18. A favorable locality for testing this anticline is in the center of the NW. ¼ NW. ¼ sec. 18. The depths of the different formations there are approximately the same as in the dry hole drilled in the SE. ¼ sec. 7, where the Bartlesville was penetrated at 1,786 to 1,846 feet and the "Mississippi lime" at 1,915 to 2,207 feet. In that hole the Bartlesville was reported to be barren of oil and water.

Lost Creek anticline.—The Lost Creek anticline, which is mainly in T. 26 N., R. 11 E., extends into this township along the line between secs. 5 and 6. There the high part of the anticline is outlined by the 910-foot contour, which is closed in the two townships. This part of the anticline shows moderately strong dips to the west and east, but on the south the beds are relatively flat. A favorable locality to test this anticline would be near the center of the NE. ¼ sec. 6. There the Bartlesville and the "Mississippi lime" may be reached at substantially the same depths as in the well in the SE. ¼ sec. 7, as stated above, allowance being made for the difference in elevation of the mouths of the wells.

AREAS OF UNFAVORABLE STRUCTURE.

T. 25 N., R. 12 E.

Oil is commonly found in the Osage country associated with anticlines, terraces, or structural noses, and most commonly on the west and northwest sides of these features; it is seldom found in major synclines or in areas of featureless normal west dips. Therefore, the areas least likely to be productive of oil are synclines such as that trending southward from sec. 29 along the line between secs. 31 and 32, T. 25 N., R. 12 E., into the adjoining township on the south and that trending south along the creek in sec. 6 to the southern edge of sec. 7, where it forks. Another unfavorable area is in the closed syncline which extends from the center of sec. 4 southward to the southern edge of sec. 9 and in its more constricted extension southward through the center of sec. 16. Oil has been found on the west flank of the Forty-seven anticline, but it probably does not extend down the dip much, if any, below the 1,050-foot contour. The low, flat syncline extending southwestward from the center of sec. 17 to the southwest corner of sec. 19 is also likely to be unproductive of oil.

T. 25 N., R. 11 E.

The southern part of secs. 32 and 33, T. 25 N., R. 11 E., are parts of a broad syncline which extends into the adjacent township to the south and will probably be unproductive of oil. The large closed syncline in secs. 3 and 4 and the lower part of the area of west dip in the western part of secs. 2, 11, and 14 and the eastern part of secs. 10 and 15 are also quite likely to be barren of commercial accumulations of oil. In general this township can best be developed by testing first the favorable folds and by drilling the productive pools until they are completely defined.

T. 26 N., RS. 9, 10, AND 11 E.

By Frank R. Clark.

INTRODUCTION.

The area described in this paper embraces T. 26 N., Rs. 9, 10, and 11 E., and lies in the eastern part of the Osage Reservation. (See fig. 1.) The country is sparsely settled, there being within this area few farms and only one small town, Okesa. The Missouri, Kansas & Texas Railway traverses the southeast corner of R. 10 E. and the central part of R. 11 E., and a new branch of the Atchison, Topeka & Santa Fe Railway (now under construction) traverses the east side of R. 9 E.

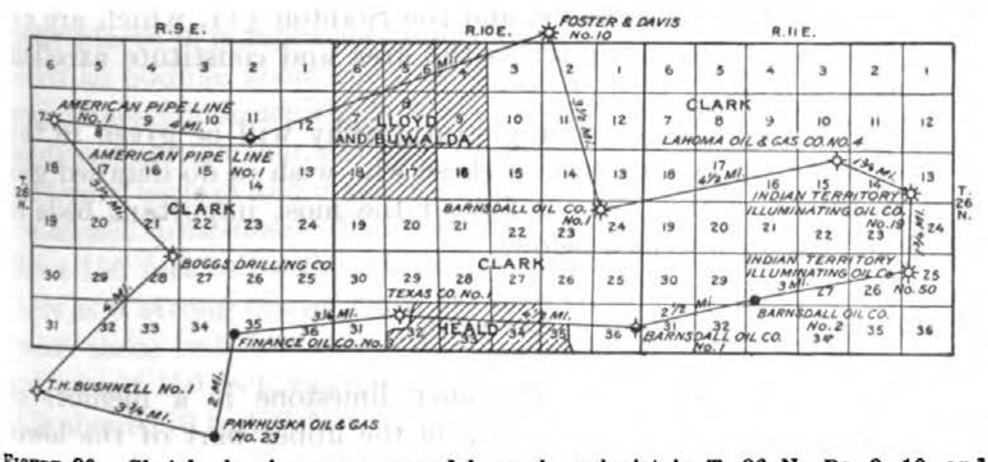


Figure 20.—Sketch showing area mapped by each geologist in T. 26 N., Rs. 9, 10, and 11 E., and location of wells shown in Plate XVII.

Field work in these townships was done for varying periods between August, 1917, and June, 1918, by K. C. Heald, W. A. English, E. R. Lloyd, J. P. Buwalda, P. V. Roundy, E. M. Spieker, and the writer, assisted by Lewis Mosburg, Earl Crandall, and R. L. Triplett, instrument men. The area mapped by each geologist is shown in figure 20. The writer, assisted by the men mentioned above, is responsible for the portion indicated without shading. The geology was mapped with plane table and telescopic alidade, but in some densely wooded areas work of this sort was supplemented by barometer and compass traverse. The barometer work was carefully checked and the structure contours throughout represent the attitude of the surface rocks.

It will be found by comparing the maps of the townships covered by this report with those of the adjacent townships that the contours match exactly except along the boundary lines between Tps. 25 and 26 N., Rs. 10 and 11 E., and T. 26 N., Rs. 11 and 12 E. The failure to match here is due to convergences in one township between certain key beds which are not present in another township and to the presence of lenticular beds which are prominent only over small areas.

STRATIGRAPHY.

ROCKS EXPOSED.

GENERAL FEATURES.

The exposed rocks in this area belong to the middle Pennsylvanian. They consist of shales, sandstones, and limestones aggregating about 900 feet in thickness, and their character and succession are shown graphically on Plate XVI. Shales and sandstones form the major part of the exposed rocks, and the shales are the more abundant. The principal limestones are the Plummer, the Lecompton, the middle bed of the Oread, the Labadie, and the Stanton (?), which are exposed from north to south across the area and constitute excellent key rocks.

No detailed description of the stratigraphy will be given in this paper, but for the convenience of those who wish to do detailed geologic mapping in this area, a few of the most important beds or key rocks will be described below.

KEY BEDS.

Plummer limestone.—The Plummer limestone is a member of the Pawhuska limestone and occurs in the upper part of the lower half of this formation. It outcrops in the west two tiers of sections in T. 26 N., R. 9 E. (see Pl. XIII), and is well developed just east and north of Plummer's ranch house, in sec. 8. It is about 9 feet thick and consists of two benches each about 1 foot thick, separated by about 7 feet of shale. The upper bench, in many places concealed by float or slump from the overlying limestone, weathers in large rectangular blocks from 6 inches to 1 foot in thickness. The rock is dark steel-gray to brown on the weathered surface, but light gray to white on fresh fractures and is massive and crystalline. In physical character and thickness the lower bench is similar to the upper bench, but it differs in containing an abundance of *Fusulina.*

Lecompton limestone.—The Lecompton limestone, described by Heald,[1] is exposed near the top of the flat divide in sec. 21, T. 26 N., R. 9 E., and is well developed farther north in Little Sand Creek. It is about 8 feet thick. In some places it is exposed in two benches, each less than 2 feet thick, separated by about 5 feet of shale, but elsewhere the lower bench is not developed or is replaced by underlying Elgin sandstone. The Lecompton, which is also a member of the Pawhuska limestone, lies 30 to 35 feet below the top bench of the Plummer limestone. It contains *Fusulina* and is of a bright lemon color on weathered surfaces and dull russet-yellow on fresh fractures.

Middle bed of Oread limestone.—The bed of the Oread limestone that is present in this area is regarded as the stratigraphic equivalent of the middle limestone bed of the Oread of Kansas. The interval between the Lecompton and Oread limestones is filled mainly with the Elgin sandstone (about 110 feet thick), and associated shales, aggregating about 205 feet in thickness. The Oread crops out in the east half of T. 26 N., R. 9 E. (see Pl. XIII), and is well developed in the Pawhuska-Bartlesville road on the west side of the big hill along the south line of sec. 36, T. 26 N., R. 9 E. In general appearance it resembles the Lecompton limestones, above described. Where well developed it rarely exceeds 2 feet in thickness, and in many places it is represented only by a thin band (1 to 3 inches) of chertlike nodules about the size of marbles. The characteristic blue-gray lime shale in which the Oread occurs and a red shale and white sandstone series about 20 to 25 feet below it render the correlation of the Oread certain and make it an excellent key rock.

Labadie limestone.—The Labadie limestone in this area occurs about 180 feet below the middle bed of the Oread, but farther south there is a strong convergence between them. Thus the distance between these beds in the southwest quarter of T. 25 N., R. 10 E., is only about 150 feet, whereas north of this area, in T. 27 N., R. 10 E., it is about 170 to 180 feet. The Labadie limestone crops out through the east-central portion of T. 26 N., R. 10 E. (see Pl. XIV), and is particularly well developed at Labadie Point, in sec. 9, and elsewhere on Rock Creek and Sand Creek. This limestone in this area is from 5 to 8 feet thick. The upper portion weathers cinnamon brown and the lower part gray brown, but on the fresh surface it is steel gray and crystalline. In many places it is highly siliceous, and where best developed it crops out in a vertical wall 5 feet or more high. It weathers out in large blocks and forms conspicuous topographic features. The bed does not contain many fossils, but in places they may be found. In T. 27 N. a still higher bench of gray to white color rests on the cinnamon-brown bed.

[1] Heald, K. C., U. S. Geol. Survey Bull. 691, pp. 67–68, 1918 (Bull. 691–C).

Revard sandstone.—The Revard sandstone, which occurs about 140 to 150 feet stratigraphically below the Labadie limestone, is well developed at Revard Point, in sec. 13, T. 26 N., R. 10 E., and elsewhere on Sand Creek in this vicinity. In several places 200 feet of nearly continuous sandstone is exposed from the top of the Revard downward, but the name is applied to the upper 30 to 40 feet, which is usually separated from the sandstone below by a thin shale that in places is bright red. The Revard is a massive, unevenly bedded quartzose sandstone. It is highly cross-bedded, and in some places the upper surface is ripple marked, but in others it is uneven, making a poor surface on which to interpret structure. In places it is overlain by a red shale containing a thin productoid-bearing sandstone, which lies from 7 to 10 feet above the top of the Revard. This thin sandstone aids in correlation and mapping and in the interpretation of the structure. Two prominent sandstones crop out between the Labadie limestone and the Revard sandstone. The upper one occurs about 15 to 25 feet below the top of the limestone. It is massive and ledge-making. The other sandstone, the Cheshewalla, described by Winchester and Heald,[1] closely resembles the Revard and occurs about 80 feet above it. This sandstone is 25 to 40 feet thick, is cross-bedded and massive, and is overlain by red shale and fossiliferous sandstone. Care must be used in mapping these sandstone beds, because the only basis for a distinction is their relative stratigraphic position.

Buck Point sandstone.—The Buck Point sandstone occurs 95 to 115 feet stratigraphically below the top of the Revard sandstone, described above. Together with the underlying shale it is well developed at Buck Point and elsewhere around the edges of the main divide between Sand and Buck creeks in T. 26 N., R. 11 E. On the north side of Buck Creek in secs. 2, 3, and 4 it is characterized by a thin productoid-bearing stratum at the top, which is easily traceable and insures definite correlations. The Buck Point sandstone is about 45 feet thick and forms a prominent bench with a vertical cliff below. It is easily traced in the field, but over the greater part of this area its only distinctive characteristic is the presence of a calcareous conglomeratic bed at or near the base, which at many places is associated with *Fusulina*-bearing sand. Except for a thin shale immediately overlying the Buck Point, the interval between the Revard and Buck Point sandstone is occupied principally by sandstone, and in a few places the entire interval is filled with sand. Below the Buck Point sandstone is a shale, which at Buck Point is about 75 feet thick and which occupies approximately the same stratigraphic position as the shale below the Bigheart sandstone, described

[1] Winchester, D. E., and Heald, K. C., report on T. 25 N., R. 10 E.: U. S. Geol. Survey Bull. 686-G, 1918.

by Hopkins.[1] The Buck Point and Bigheart are, however, not continuous and are probably not at exactly the same stratigraphic horizon. They are therefore given different names.

Okesa sandstone.—The Okesa sandstone, so called because it crops out near the railroad station and town of Okesa, forming the first prominent bench half a mile to the southeast, occurs 65 to 115 feet below the Buck Point sandstone. The maximum distance was measured at Buck Point and the minimum on Paula Creek south of Okesa, and there is thus a 50-foot convergence between these sandstones toward the south and west. The Okesa is 20 to 30 feet thick and is well developed on both sides of Sand Creek as far west as Okesa but passes below drainage level in the bed of Sand Creek at the Bartlesville-Pawhuska wagon road crossing half a mile north of Okesa. It is also well developed on both sides of Little Rock Creek, and the outcrop extends southward into T. 25 N., R. 11 E. In the vicinity of Okesa it is confined to one bed which contains numerous pelecypods and a few brachiopods, but in most places within this area two benches are developed, separated by shale. The lower bench is generally massive and forms a ledge, and its upper surface contains fossils. A thin nodular limestone crops out at many places about 5 feet above the lower bench. The upper bench, which is from 10 to 13 feet above the lower, is thinner and not so well exposed, but wherever seen it contains many pelecypods. A shale from 25 to 60 feet thick occurs below the Okesa and above the Torpedo sandstone.

Torpedo sandstone and Stanton (?) limestone.—The Torpedo sandstone, which crops out over a large area in the eastern part of T. 26 N., R. 11 E., occurs about 65 feet below the top of the Okesa sandstone, but in places the stratigraphic distance between these beds varies as much as 50 feet. The distance between the Okesa and Torpedo sandstones in the SE. ¼ sec. 7, T. 26 N., R. 12 E., is 75 feet, and near the center of sec. 1, T. 26 N., R. 11 E., it is not more than 25 feet, showing a convergence of 50 feet in a distance of less than 2 miles. Other convergences, though not so great, occur near Buck Point and to the southwest. The torpedo sandstone is 20 to 30 feet thick, is massive, and in general forms a ledge. In many places its upper surface is filled with tubelike openings. An impure siliceous limestone, probably the Stanton, occurs above the Torpedo sandstone. The limestone is generally separated from the sandstone by 2 to 9 feet of blue-gray limy shale, containing crinoid stems, but in a few places it rests directly on the sandstone. The limestone, though generally thin, is in some places several feet thick. It contains many crinoid stems and locally other fossils. It weathers lemon yellow, but on fresh fracture is steel gray. The Torpedo sandstone and the Stan-

[1] Hopkins, O. B., report on T. 25 N., Rs. 11 and 12 E.: U. S. Geol. Survey Bull. 686–H, 1918.

ton (?) limestone are well developed in the bluff on the north side of Sand Creek 1 mile northwest of Torpedo siding and also at many places on Little Rock Creek and along the Pawhuska-Bartlesville road on the north side of Sand Creek.

ROCKS NOT EXPOSED.

Records of wells in this area show that between the surface rocks and the Big lime occur shale, sandstone, and limestone, and that the shale aggregates a greater thickness than the sandstone and limestone combined. Between the Big lime and the "Mississippi lime" shale and limestone predominate, but there are a few prominent sandstones which yield oil and gas. The character of the rocks is clearly indicated in Plate XVII, in which is shown graphically the drillers' interpretation of the rocks penetrated in several selected wells in this area. These records are alined on the horizon of the middle bed of the Oread limestone as a datum.

The Big lime is the first key bed that the driller has attempted to recognize, and therefore his interpretation of the rocks above it is in many logs only roughly recorded and in many others unfortunately not recorded at all. Correlations of beds above the Big lime, from well logs now available, must be based on relative positions. The irregularities shown in the intervals between certain prominent sandstones or limestones may be in part true irregularities, due to variations in the conditions of deposition and in part simply the result of errors in measuring or recording the log. From a study of surface rocks it is known that prominent beds vary in thickness and that strong convergences exist between these beds, but many logs show impossible conditions. It is therefore suggested and urged that the utmost care be taken in future drilling to record the log accurately from the surface to the bottom of the hole, because such a record will materially aid the geologist and also the driller in the interpretation of these rocks and of their bearing on the production of oil. The driller has taken more pains to record the character of the rocks between the top of the Big lime and the "Mississippi lime," probably because most of the oil produced at present comes from that interval and also because these beds contain characteristics which he more easily recognizes.

The distance between the horizon of the middle bed of the Oread limestone and the Big lime ranges from 1,350 feet in sec. 7, T. 26 N., R. 9 E., to about 1,580 feet in sec. 25, T. 26 N., R. 11 E., and averages about 1,500 feet for the logs shown in Plate XVII.

Below the Big lime is a sandstone and shale series aggregating 65 to 110 feet, followed by a limestone (the Fort Scott) 60 to 100 feet thick, usually called "Oswego lime" by the drillers. The Peru sand, normally present between the Big lime and the "Oswego lime," is either absent in several of the wells whose logs are shown in Plate XVII or the drillers failed to recognize it. The Peru sand in places in Osage County is productive of oil. The "Oswego lime" is usually separated into several benches by partings of black shale, a characteristic which aids the driller in recognizing this key bed. Showings of gas are reported from this bed, but no big yield is known in this vicinity. Below the "Oswego lime" and above the "Mississippi lime" is a series of shale, sandstone, and thin limestone from 250 to 375 feet in thickness in which the shale aggregates many times the amount of sandstone and limestone. The productive oil and gas sands in this interval are the Squirrel and Bartlesville. The Squirrel sand ranges from 10 to 138 feet in thickness and, according to most of the logs studied, is separated from the "Oswego lime" by shale, but in several places the lime rests directly on the sand. The beds between the Squirrel and the Bartlesville consist mainly of shale with a number of thin limestones, one of which is the so-called Pink lime, which in some parts of Osage County is easily recognized by the driller. Between the Pink lime and the "Mississippi lime" is a series of sandstone interbedded with shale. Any productive sand in this interval is called Bartlesville by the drillers, and in this region the Bartlesville embraces the basal portion of the Cherokee—that is, of the Pennsylvanian. Several wells in this area have gone below the Bartlesville and associated sands and reached a limestone commonly called the "Mississippi lime," which probably represents the Boone limestone of northeastern Oklahoma and Kansas, but the correlation is not at present absolutely certain. Its thickness is not known, because it has not been completely penetrated, but at several places in Osage County beds below the top of this lime have yielded oil and gas in commercial quantities. It should be tested to a depth of 300 feet in areas of distinctly promising structure.

A study of the logs of wells drilled in this area shows many irregularities in the thickness and character of the rocks between certain recognizable key beds but reveals a very significant fact, namely, that between the surface beds and the "Mississippi lime" there is a strong divergence toward the south and east. The well logs are so chosen (see fig. 20) that by combining certain logs profile sections may be had in almost any direction. As they are arranged in Plate XVII they show roughly north-south and east-west profiles. The "Mississippi lime" is stratigraphically more than 400 feet deeper at the southeast corner of T. 26 N., R. 11 E., than it is at the northwest corner of T. 26 N., R. 9 E. The few available detailed well logs show variations in the position of the "Mississippi lime," but as a whole the logs shown in Plate XVII are convincing and are sufficient to establish the existence of this strong divergence.

STRUCTURE.

AREAS OF FAVORABLE STRUCTURE.

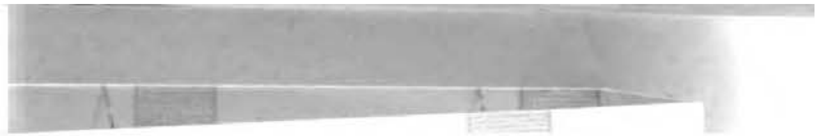
GENERAL FEATURES.

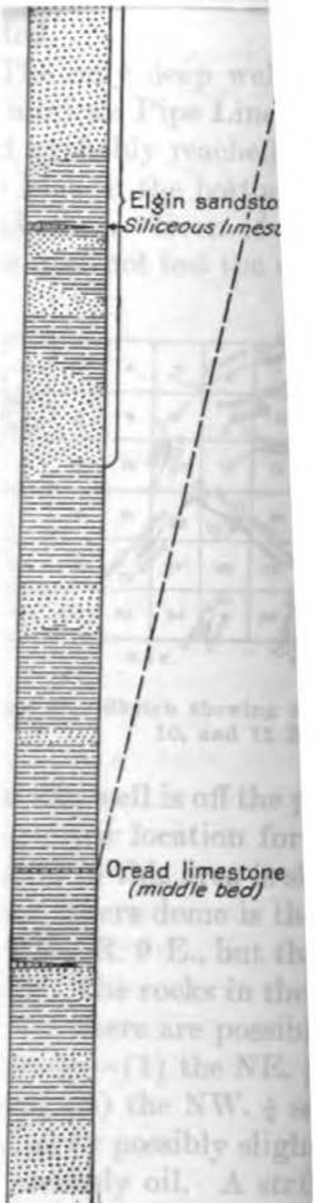
The area covered by this report is a portion of a much large region in which the general dip of the rocks is to the west and northwest. The presence of an east dip is therefore significant, because it indicates an upfold that may yield commercial quantities of oil and gas.

A study of the trend of oil production in many developed fields in Osage County indicates that in general the oil occurs in areas of anticlinal structure and that it has migrated up the dip from the west. There appears to have been little migration of oil along the strike of the rocks, even in small folds, because in many of the folds commercial production is confined largely to the west flank unless the uplift is large and there is considerable gathering ground in other directions. In testing the oil possibilities of any fold one or even two dry holes which are structurally favorably located should not condemn the fold, because a "tight sand" may prevent the accumulation of oil in one part, whereas in another part an "open sand" may yield a good quantity of oil. No well favorably located structurally should be considered a failure until it has penetrated the "Mississippi lime" at least 300 to 400 feet. Sites for test holes are indicated on the accompanying maps (Pls. XIII–XV). These sites are chosen with reference to structure and may be shifted slightly if necessary to obtain favorable topographic positions.

The rocks in the west half of T. 26 N., R. 9 E., and the central, northwestern, and southeastern parts of T. 26 N., R. 10 E., dip gently to the west, with few marked irregularities, in conformity with the regional structure. The rocks in the east half of T. 26 N., R. 9 E., the southwest and northeast corners of T. 26 N., R. 10 E., and all of T. 26 N., R. 11 E., are more closely folded, producing many uplifts which are favorable for the occurrence of oil and gas. There are few faults in this area, the principal ones being confined to the east half of R. 9 E., although a few are found elsewhere. The structure is shown by means of contours on the maps. These contours are based solely on surface data and are drawn on a theoretical bed 560 feet below the top bench of the Plummer limestone.

For convenience in description the folds that are favorable for oil will be described from west to east, beginning with the Myers dome, in the northwest corner of T. 26 N., R. 9 E. (See fig. 21.)

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Oread limestone
(middle bed)

ANTICLINES IN T. 26 N., R. 9 E.

MYERS DOME.

The Myers dome is a nearly symmetrical dome with a small crown situated near the center of sec. 12, T. 26 N., R. 8 E. It has a closure of more than 70 feet, and the lowest closed contour incloses about 3 square miles, of which about half a square mile lies in the W. ½ sec. 7, T. 26 N., R. 9 E. A shallow sand is now yielding gas from this dome, but oil and gas sands deeper than 1,000 feet have not been tested.

The only deep well near the dome is in the SW. ¼ NE. ¼ sec. 7 (American Pipe Line No. 1). It was drilled to a depth of 2,250 feet and probably reached the "Mississippi lime" at 2,180 feet, although the lime in the bottom of the hole may be about the horizon of the Pink lime. Even if the drill reached the "Mississippi lime," this hole does not test the oil and gas possibilities of the deeper sands, be-

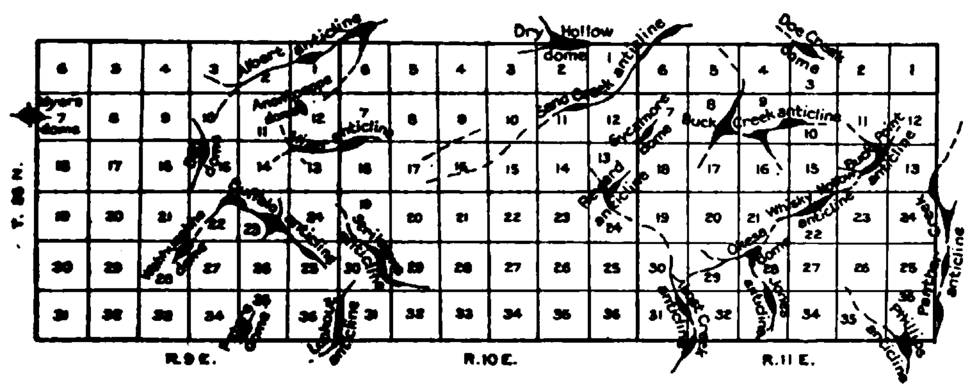

FIGURE 21.—Sketch showing roughly the position of anticlinal axes in T. 26 N., Rs. 9, 10, and 11 E., shaded to indicate the crests of folds.

cause the well is off the productive area and in the bordering syncline. The proper location for a test well for that part of the Myers dome situated in this area is shown on Plate XIII.

The Myers dome is the only pronounced uplift in the west half of T. 26 N., R. 9 E., but there is a considerable area that may yield oil or gas. The rocks in the west two tiers of sections are comparatively flat, but there are possibly three areas in which they may be slightly bowed up—(1) the NE. ¼ sec. 8, (2) the SW. ¼ sec. 17 and NW. ¼ sec. 20, and (3) the NW. ¼ sec. 19. Structurally these areas are low, flat terraces or possibly slight upwarps and may catch and hold some gas and possibly oil. A striking northwest fault cuts the surface rocks in secs. 19 and 29. The greatest displacement, 10 feet, is in the SE. ¼ sec. 19, and the downthrow is on the east.

A belt of steeply dipping rocks extends from north to south through the middle of T. 26 N., R. 9 E. This belt is considered fairly favorable for the accumulation of oil, and test wells should be drilled near the top of the steeply dipping zone. The "Mississippi lime" will probably be reached within 2,200 feet.

BEN DOME.

The crown of the Ben dome is in the NW. ¼ sec. 15, T. 26 N., R. 9 E. It has a closure of less than 20 feet, and the lowest closed contour incloses an area of about a quarter of a square mile. This dome has an ample gathering area and is structurally very favorable for the accumulation of oil. The crown probably contains gas, and tests for oil should therefore be drilled on the west flank at locations shown on the map (Pl. XIII).

Of these the most promising is that in the NE. ¼ sec. 16, where the "Mississippi lime" will probably be reached within 2,200 feet, but the well at this site should be drilled to a depth of 2,500 feet to constitute a thorough test. If the test wells prove successful commercial production of oil is to be expected in the SE. ¼ sec. 9 and the E. ½ sec. 16.

ALBERT ANTICLINE.

The portion of the Albert anticline within this area is a long anticlinal nose trending west and southwest from the crest of the uplift in sec. 31, T. 27 N., R. 10 E., to sec. 10, T. 26 N., R. 9 E., where it is separated from the Ben dome by a shallow syncline. In the N. ½ sec. 1, a small dome, marked by one closed contour, occurs on the axis of this nose (see Pl. XIII), which structurally is the most favorable location for a test of the oil and gas possibilities of the Albert anticline in this great area, but a site on the main crest of the uplift in sec. 31, T. 27 N., R. 10 E., is the most favorable for a test hole. The "Mississippi lime" in the test hole indicated on Plate XIII is believed to lie at a depth of 2,050 to 2,100 feet, but the test well in the NW. ¼ sec. 1 should be drilled at least 2,400 feet. If this test proves successful, oil in commercial amounts may be expected in each direction, especially westward. The anticlinal nose, which extends through sec. 2 and into sec. 10 structurally, also has fair possibilities for the accumulation of oil, especially in the SW. ¼ sec. 2, where the gently dipping strata pitch westward into the steeply dipping monocline.

ANONTOOPPE DOME.

The Anontooppe (a-non-to-op′pe) is a small flat-topped dome having a closure of less than 20 feet and an inclosured circular area of about 100 acres. It is limited on the south by a broad, shallow syncline and on the east by a faulted syncline. The fault trends northwest and has a maximum downthrow of about 20 feet on the

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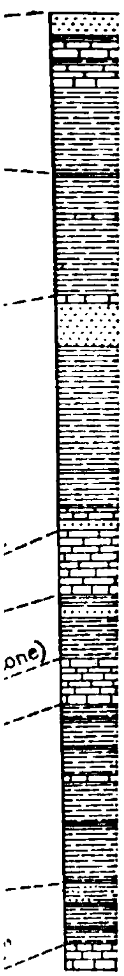

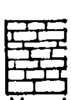

west. The dome has a good gathering area to the west, and so far as its structure is concerned may be expected to yield considerable oil, although it is probable that the crown will yield gas. The best location for a test is shown on Plate XIII. The "Mississippi lime" should be reached here at a depth of about 2,050 to 2,100 feet, but the dome should not be condemned by an unsuccessful well less than 2,400 feet deep.

BUFFALO ANTICLINE.

The Buffalo anticline is the most pronounced uplift in T. 26 N., R. 9 E. It affects the attitude of the rocks over several square miles. The axis of the anticline, on which there are three domes separated by shallow structural saddles, is roughly crescent shaped and trends southeastward through secs. 22, 23, 24, and 25. (See Pl. XIII and fig. 21.) The uplift is limited on the south and east by deep synclines which are accentuated by faulting, but on the west a long monocline extends for several miles. The normal attitude of the rocks affected by the uplift in the SE. ¼, T. 26 N., R. 9 E., has been distorted at several places by northwestward-trending faults. This complexly faulted area is part of a larger northeastward-trending zone of weakness across the Pawhuska quadrangle, in Osage County, in which the rocks are displaced and shattered. Three faults cut the rocks in the E. ½ sec. 22. The vertical displacement of each is less than 10 feet, and therefore, unless they are accentuated in the vicinity of possible oil-bearing sands, they have had little effect on the migration or accumulation of oil. Two other faults, about 500 to 1,000 feet apart, cut the rocks on the south side of this fold in secs. 26 and 36 and greatly alter the trend and shape of the bordering syncline. The maximum vertical displacement of these faults appears near the northeast corner of sec. 35, where the west block of the west fault has been dropped about 10 feet and the east block of the east fault has been dropped about 30 feet. The maximum displacement of these faults, if it continues to the possible oil-bearing sands, is thought to be sufficient to retard the migration of oil and perhaps to offset oil or gas sands completely, so that an accumulation of oil might result. Three other faults in secs. 24, 25, and 36 limit or cut off the anticline on the east and convert the normal east flank of the uplift into a syncline. The west block of the west fault has a maximum downthrow of 10 feet near the center of the SE. ¼ sec. 25. The middle fault is the largest and is of the scissors type. The hinge or point of zero throw is in the SE. ¼ sec. 25, near the axis of the syncline that separates the Buffalo and Lookout anticlines. North of this point the maximum displacement is in the SW. ¼ sec. 24, where the east block has been dropped 50 feet; south of the hinge point the maximum displacement is in the SE. ¼ sec. 25, where the west block has been dropped 10 feet. The east fault has its maximum throw near the line between secs. 13 and 24, where the east block has been dropped 25 feet. The throw of each of the three faults above described diminishes rapidly in either direction, and each fault passes into a flexure within less than a mile from the point of maximum displacement. If the displacement of the rocks due to the faults continues to the oil sands, it is sufficient to retard migration up the bordering syncline on the north, and would result in a small accumulation of oil on the northeast flank of the highest dome of the Buffalo anticline.

The center and highest dome of the Buffalo anticline, in the SE. ¼ sec. 23, has a closure of nearly 40 feet and an inclosed area of about half a square mile. Its axis trends southwest, or transverse to that of the main uplift, and pitches in either direction, terminating in bordering synclines. The long monocline on the northwest and southwest flanks affords ample gathering ground for a considerable accumulation of petroleum. The crown of this dome has been drilled, and several gas sands are reported—at 317 to 328 feet, yielding 5,000,000 cubic feet; at 420 feet, 2,000,000 cubic feet; and at 2,105 feet, 5,000,000 cubic feet. The deep producing sand is the upper part of the "Mississippi lime" of the drillers. As the crown of the dome yields gas, it is very probable that the flanks will be oil bearing, but just where the line between the oil and gas may be is difficult to predict. Locations for test oil wells are shown on the map (Pl. XIII). The more favorable of these two is that in the SW. ¼ sec. 23, where the "Mississippi lime" is believed to lie at about 2,075 feet, but the well should be drilled to a depth of at least 2,400 feet to constitute a thorough test. It seems probable that oil may be expected in the NE. ¼ and the W. ½ sec. 23 and in the NW. ¼ sec. 26.

The dome at the northwest end of the axis of the Buffalo anticline is considered favorable oil and gas territory. It has a closure of nearly 20 feet and a pear-shaped inclosed area of about 40 acres. Three faults have slightly displaced the surface rocks affected by this dome, but they are too small, unless they are accentuated below the surface to influence seriously the migration and accumulation of oil. The long monocline extending westward from the dome gives an excellent gathering ground. It seems very probable that the inclosed area of this fold will yield gas, and therefore the test oil wells should be on the west flank. Locations recommended for these wells in the NE. ¼ sec. 22 are shown on Plate XIII. The location nearest the center of the section is preferable, being at the top of a zone of steeply dipping beds and on a southwestward-plunging nose of the anticline. The "Mississippi lime" at this point may be expected at a depth of about 2,125 to 2,150 feet. Should this test prove successful, development should be extended toward the west, south, and east; should it yield neither oil nor gas, the next test should be made on the crown of the dome.

The dome at the southeast end of the axis of the Buffalo anticline is considered fair oil and gas territory. It is separated from the highest dome of the Buffalo anticline on the north by a structural saddle, and from the Lookout anticline on the southeast, in T. 26 N., R. 10 E., by a shallow syncline. Faults convert the east flank into a syncline and are so situated that they may retard migration and aid in the accumulation of petroleum at the crest. The gathering ground for this dome is relatively small because the faults in secs. 26 and 36 may cut off migration, but oil may find its way around the faults or even across them if the oil-bearing stratum is not entirely offset. The location for a test well shown on the map is on the crest near the north end, where the "Mississippi lime" should be reached at a depth of about 2,100 feet, but a thorough test requires drilling to at least 2,400 feet. A study of the productive areas in some of the best-developed and largest fields in Osage County leads to the conclusion that oil may be expected to extend from the Wahhusahhe dome into the Buffalo anticline in secs. 22 and 23, possibly the southwest corner of sec. 24, the E. ½ W. ½ sec. 25, and sec. 26 except the SE. ¼.

WAHHUSAHHE DOME.

The Wahhusahhe (wah-hu-sah'he) dome is a small uplift whose crown is in the NW. ¼ sec. 27 and the NE. ¼ sec. 28. It has a closure of about 10 feet, and its one closed contour incloses less than 40 acres. It has ample gathering ground to the west and north but is narrowly limited on the south and east by a shallow syncline. A well was drilled near the crown to a depth of 2,078 feet, and the log reported "Mississippi lime" at 2,060 feet. It is significant that no oil or gas is reported from the shallow sands which are producing gas in the Myers dome, in sec. 12, T. 26 N., R. 8 E., and in the Buffalo anticline, in sec. 23, T. 26 N., R. 9 E. This well does not, however, condemn the Wahhusahhe dome, because from the best information available from well records the dry hole failed to reach the "Mississippi lime" by about 100 feet. The lime reported at 2,060 feet may be either the Pink lime or another associated with it. The test well at the site indicated on the map (Pl. XIII) should be drilled to a depth of 2,400 to 2,500 feet before condemning the dome. If the test well proves successful, oil will probably be obtained both west and northwest of it, but the productive area will be small, because the rocks are affected by the folding over only a small area.

PETERS DOME.

The name "Peters dome" is applied to a small part of a considerable terrace in sec. 35, which is indicated on Plate XIII by one closed contour. A broad syncline borders the terrace on the east and the southwest. Four wells on the crown are producing oil from the "Mississippi lime," and two dry holes are reported on the east flank, or near the bordering syncline, which appears to limit the productive area in that direction. According to the structure, future development should extend northward and probably southward to the section line.

ANTICLINES IN T. 26 N., R. 10 E.

MIZER ANTICLINE.

The Mizer anticline is a low uplift, with a closure of less than 20 feet and a circular inclosed area of about 160 acres, in the SW. ¼ sec. 7 and the NW. ¼ sec. 18, T. 26 N., R. 10 E. A long, flat anticlinal nose extends westward to the west line of sec. 13, T. 26 N., R. 9 E., where it pitches westward into a monocline. A deep eastward-trending syncline separates this anticline from the Buffalo and Strikeaxe anticlines, to the south, and a shallow, narrow syncline separates the Anontooppe dome and Mizer anticline. Two locations are suggested for test holes on this anticline. (See Pls. XIII and XIV.) The "Mississippi lime" should be reached in the NW. ¼ sec. 13, T. 26 N., R. 9 E., at a depth of about 2,050 to 2,100 feet, and in the NW. ¼ sec. 18, T. 26 N., R. 10 E., at about 2,000 feet, but if necessary these tests should be drilled to 2,300 or 2,400 feet.

LOOKOUT ANTICLINE.

The axis of the Lookout anticline trends north in sec. 31 along the township line between Rs. 9 and 10 E. It has a closure in this area of about 20 feet and an inclosed area of about 200 acres. A prominent anticlinal nose trends southwestward across the center of sec. 1 and into sec. 2, T. 25 N., R. 9 E., where a small dome is developed at the end of the nose. This part of the anticline in T. 25 N., R. 9 E., is described by Heald.[1] The Lookout uplift is bordered on the east and west by well-developed synclines, and on the north and northeast it is separated from the Buffalo, and Strikeaxe anticlines by shallow synclines or structural saddles. There is fair gathering ground to the west and southwest and no surface evidence to prevent or retard the migration of petroleum into the crest of this fold. A small northwestward-trending fault with a maximum throw of less than 10 feet cuts the surface rocks on the crest of this anticline in sec. 1, T. 25 N.,

[1] Heald, K. C., report on T. 25 N., R. 9 E.: U. S. Geol. Survey Bull. 686–E, 1918.

R. 9 E., but it can have little or no effect on the accumulation of petroleum. This anticline is now being tested. There are two producing wells, one yielding gas and one oil, and two other wells being drilled (August 15, 1918). (See Pls. XIII and XIV.) The detailed logs are not yet available, so the source of the output is not known. The producing wells are nearly on the crest of the anticline, and therefore development should extend between them and westward. The oil well is at the north end, near the point where the axis plunges into the syncline. Structurally the E. ½ sec. 36, T. 26 N., R. 10 E., is favorable for oil production.

STRIKEAXE ANTICLINE.

The Strikeaxe anticline has a crescent-shaped northwestward-trending axis in secs. 29 and 30, T. 26 N., R. 10 E. It has a closure of about 25 feet and an inclosed area of about three-quarters of a square mile. It is limited on the north, east, and south by well-developed synclines. The one on the south is a broad, flat, shallow depression; those on the north and east are deeper and narrower. The Strikeaxe and Lookout anticlines are separated by a narrow structural saddle, and it is not unlikely that the productive area may extend across the saddle from one anticline to the other. The presence of oil and gas in the Lookout anticline places the Strikeaxe anticline almost adjacent to an area that is now producing. This anticline has a considerable gathering area, especially to the northwest, which renders the north and west flanks much more favorable for oil production than the east and south flanks. The broad, flat syncline on the south is not particularly favorable for the migration of petroleum, and the south flank of the Strikeaxe anticline is too short to afford a large accumulation. The results of a dry hole on the south flank in the NW. ¼ sec. 32 enhance the value of the fold rather than condemn it, for although this well is structurally unfavorably located showings of gas were reported at depths of 870, 950, and 1,090 feet, all above the Big lime, and at 2,100 feet, in the top of the "Mississippi lime." This suggests that the east end of the crest of the fold may yield gas or oil, and structurally the north end is much more favorable. Locations for test holes are shown on Plate XIII. The one on the crown may yield gas, but that on the north end of the anticline should yield oil. The "Mississippi lime" should be reached in the test on the crown at about 2,125 to 2,150 feet and in the one at the north end at about 2,050 to 2,100 feet.

Two locations for test holes in sec. 16, T. 26 N., R. 10 E., are indicated on Plate XIV. The structure here is less favorable for the accumulation of oil than it is on pronounced closed uplifts, but, nevertheless, tests for oil and gas are warranted. These locations are on rather prominent anticlinal noses, which plunge westward into a steeply dipping monocline that terminates in a pronounced depression in secs. 18 and 19, T. 26 N., R. 10 E. The monocline affords good gathering ground, and the zone of steeply dipping rocks followed by the flat anticlinal noses affords favorable conditions for the accumulation of oil. The "Mississippi lime" in these test holes should be reached at about 2,000 feet. Should either or both tests prove successful, further development should first extend westward.

DRY HOLLOW DOME.

The Dry Hollow dome is a prominent uplift in Tps. 26 and 27 N., R. 10 E. The rocks affected by the folding lie in secs. 2 and 3, T. 26 N., and secs. 34 and 35, T. 27 N. The long axis of the dome trends east just south of the township line. It has a closure of about 25 feet and an elliptical inclosed area of nearly half a square mile. The fold is limited on the southeast by a southward-pitching syncline which on the north merges into a broad, flat depression. On the southwest, west, and northwest a long westward-dipping monocline extends for several miles from the crown of the dome and affords ample gathering area for a considerable accumulation of oil and gas. The crown of the dome yields oil from the Bartlesville sand and gas from the "Mississippi lime." Many of the oil wells make some gas, but the Bartlesville sand is not a heavy gas producer here. The "Mississippi lime" has been penetrated only near the crown of the dome, where it is gas bearing, and it will very probably yield oil on the west flank. Future development should be extended south and west from present producing wells in this area. The dry holes near the syncline limit the probable productive area on the southeast, but the dry holes adjacent to producing wells on the southwest flank may not indicate the limit of production in that direction, because an oil well in the SW. ¼ sec. 2 is not as favorably situated on the dome as the dry holes north of it. The dry holes are probably due to "tight sands" or other local conditions. The largest producing wells (50 to 60 barrels) on the dome in T. 26 N. are in the NE. ¼ sec. 3, and producing wells extend down the west flank as low as the 750-foot contour. The future possibilities of this dome appear bright, and before it is abandoned the "Mississippi lime" should be thoroughly tested—first by a number of holes drilled well down on the west flank (probably in the NE. ¼ sec. 3) to determine the oil possibilities of the beds which are producing gas on the crown; and, second, by one or more tests favorably located on the dome and penetrating the "Mississippi lime" to a depth of 300 or 400 feet.

SAND CREEK ANTICLINE.

The crest of the Sand Creek anticline is in sec. 31, T. 27 N., R. 11 E., but a long anticlinal nose trends southwestward through secs. 1 and 12 and into sec. 11, T. 26 N., R. 10 E., where it pitches westward into a long monocline. The closure of the crest is about 25 feet, and the inclosed area covers about 1 square mile. The rocks affected by this folding cover about 6 square miles and are situated in the adjoining corners of four townships, Tps. 26 and 27 N., Rs. 10 and 11 E. The uplift is limited on the south and east by a major well-developed northeastward-trending syncline, which is broad and shallow through sec. 6, T. 26 N., R. 11 E., and it is separated from the Dry Hollow dome, on the west, by a southward-pitching syncline. A number of wells have been drilled on various parts of this anticline. On the west flank of the main crest in sec. 31, T. 27 N., R. 11 E., and sec. 36, T. 27 N., R. 10 E., several oil wells and at least one gas well have shown good yields from the Bartlesville sand. That part of the anticline lying in the area covered by this report, however, has not been properly tested. In this township a well in the NW. ¼ sec. 1 is now abandoned though still making some gas, and a dry hole is reported near the east quarter corner of the same section, but this report was not verified in the field. The latter hole is not especially well located structurally, but no record is available, and therefore it may not constitute a thorough test even of this part of the fold. This anticlinal nose should yield considerable oil along its west flank, especially in the NE. ¼ sec. 11, where a small dome is developed at the end of the nose. The long monocline on the west affords a good gathering area for a considerable accumulation of petroleum. At the location for a test hole indicated on Plate II, the "Mississippi lime" will probably be reached at about 1,900 feet. If this test proves successful, all sec. 11 but the S. ½ S. ½ may be expected to produce oil.

REVARD ANTICLINE.

The Revard anticline is a long anticlinal nose with northwestward-trending axis and in a broad way is a part of the Lost Creek anticline in the southwest corner of T. 26 N., R. 11 E. It has a small dome at the north end, indicated on Plate XIV by one closed contour, which incloses about 40 acres. It is limited on the north and east by a major syncline with pronounced depressions in sec. 12, T. 26 N., R. 10 E., and sec. 19, T. 26 N., R. 11 E. A long, nearly uniform monocline extends west and southwest for several miles from the crest of this nose and affords excellent gathering area for a considerable accumulation of petroleum. It is very probable that the crest of the anticline will yield gas, but the west flank should yield considerable oil. A well on the west flank near the 840-foot contour (see Pl. XIV), in the NW. ¼ sec. 24, is yielding gas from the "Mississippi lime," and this indicates that a well in the SW. ¼ sec. 13, T. 26 N., R. 10 E., will probably yield gas. The location for a test hole shown on Plate XIV is a little higher on the fold than the gas well in sec. 24, and from structural considerations, therefore, a well here may yield gas, but it is also a favorable location to test the westward-plunging nose of the anticline. If it yields only gas, a second well should be drilled 1,000 feet due west. The "Mississippi lime" at the test site indicated on the map is believed to lie at a depth of about 1,850 feet and 1,000 feet to the west at about 1,775 to 1,800 feet. According to the structure, the most favorable part of this anticline for the accumulation of oil lies is the E. ½ sec. 14, the NE. ¼ sec. 23, and the NW. ¼ sec. 24.

ANTICLINES IN T. 26 N., R. 11 E.

LOST CREEK ANTICLINE.

The Lost Creek anticline has a northward-trending axis extending from secs. 5 and 6, T. 25 N., R. 11 E., into sec. 31, T. 26 N., R. 11 E. A long anticlinal nose extends northwestward through secs. 30 and 19, T. 26 N., R. 11 E., and joins the Revard anticline in secs. 13 and 24, T. 26 N., R. 10 E. Two domes rise on the crest of this uplift; the south one, in sec. 32, T. 26 N., R. 11 E., has a closure of nearly 10 feet and its one closed contour incloses about 80 acres; the north one, in sec. 31, has a closure of nearly 20 feet and an inclosed area of about 60 acres. The uplift is limited on the north and east by deep synclines. A long uniform monocline extends westward for about 5 miles from the crest of the anticline and affords a large gathering area with no structural features to prevent migration of oil and gas up the dip to the east. This anticline includes a large area which is structurally very favorable for oil production. No adequate test has been made of it, for the only well yet drilled, though it reached the "Mississippi lime" and obtained a showing of oil, was not very favorably located structurally. This well is near the east quarter corner of sec. 36, T. 26 N., R. 10 E., on the west flank of the Lost Creek anticline, at the upper end of a small terrace. Wells in similar structural situations have proved productive in some parts of Osage County, but this is not an established rule, for in other places the lower part of the terrace in the zone of the steeply dipping beds is the productive area. This well, therefore, does not condemn the oil possibilities of this fold, and in any event one dry hole should never be considered as completely condemning an area of favorable structure. Several locations for test holes are suggested on Plate XV. The one in the SE. ¼ sec. 31, T. 26 N., R. 11 E., is intended to test the oil and gas possibilities of the south dome of the anticline. The crest of this dome will probably contain gas, but the west flank is very favorable oil territory. The "Mississippi lime" should be reached in this test hole at about 1,825 to 1,850 feet. If this well should produce gas, the next well should be drilled 1,000 feet to the west. The test hole in the NW. ¼ sec. 31, T. 26 N., R. 11 E., should reach the "Mississippi lime" at about 1,800 to 1,825 feet, and, to judge from the structure, should yield a good supply of oil. The crown of the dome in the NE. ¼ sec. 31 is almost sure to yield gas if open sands are continuous, but it should be tested. The test hole in the NE. ¼ sec. 30 should reach the "Mississippi lime" at about 1,700 to 1,750 feet. Should these test holes prove successful oil wells, further development should be extended in every direction to determine the limits of the pool, especially to the west, where the most favorable territory lies. If these holes produce gas, other tests for oil should be made down the dip to the west.

SYCAMORE DOME.

The Sycamore dome is a small uplift on a structural terrace. It has a closure of nearly 30 feet and an inclosed area of one-third of a square mile in the SW. ¼ sec. 7, T. 26 N., R. 11 E. It is limited on the northwest and south by a well-developed syncline and is separated from the large Buck Creek anticline on the east by a narrow, shallow depression. Although the closure of this dome is sufficient to afford a good catchment area the gathering ground is limited to the synclinal area on the west, and the production, if any, will probably be less than in domes with large gathering areas. This dome is untested, and two locations for test holes are suggested on Plates XIV and XV. At these places the "Mississippi lime" should be reached at about 1,900 to 1,925 feet. The crown may yield gas, and if so oil will probably be encountered down the west flank.

The axis of the Sand Creek anticline, which is described on page 107, under the discussion of anticlines in T. 26 N., R. 10 E., traverses the northwest corner of sec. 6, T. 26 N., R. 11 E. A location for a test hole in this section is indicated on Plate XV. If this test proves successful further development should extend westward, but the productive area will probably be small, because the southeast flank of this anticline in this township is structurally unfavorable for oil accumulation.

BUCK CREEK ANTICLINE.

The Buck Creek anticline is a large upfold with an eastward-trending axis extending through secs. 8, 9, and 10, T. 26 N., R. 11 E. It consists of three minor anticlines separated by low structural saddles. The rocks affected by the major uplift cover about 7 or 8 square miles. The anticline is practically surrounded by well-developed synclines.

The normal attitude of the rocks in sec. 17 is affected by two north-northwestward-trending faults. The east block of the west fault has been dropped a maximum of less than 10 feet, and the west block of the east fault has been dropped a maximum of about 30 feet. The center of the line on the map (Pl. XV) representing the trace of each fault indicates approximately the point of the maximum throw. The throw diminishes in each direction and dies out within half a mile of the point of maximum displacement.

The west anticline of the Buck Creek uplift, in secs. 5, 8, and 17, has a northeastward-trending axis about 2 or 3 miles long which runs transverse to the axis of the main fold. It has a closure of nearly 20 feet and an inclosed area of about 40 acres. It is separated from the middle anticline by synclinal reentrants which terminate in a low structural saddle between secs. 8 and 9. The steeply dipping southwest, west, and northwest flanks afford good gathering area for the accumulation of considerable petroleum. The anticline has been tested by gas-producing wells on the crest and oil wells on the northward and southward pitching anticlinal noses as well as near the upper portion of the synclinal reentrant on the southeast flank of the anticline. The oil wells are all small producers, and several dry holes are reported alongside of oil wells, a relation which indicates variable sand conditions. Structurally the west flank of this anticline is very promising oil territory, for the long monocline extending westward furnishes a good gathering area and the crest of the fold and its steeply dipping west flank afford favorable conditions for oil accumulation. Locations for further testing the oil possibilities of the anticline are shown on the map (Pl. XV). The oil on the south and east flanks of this anticline probably comes from the Bartlesville sand, and that on the northward-pitching nose comes from about the position of the Peru sand between the Big lime and the "Oswego lime." Some of the dry holes in secs. 4 and 9 were drilled to the "Mississippi lime," but the locations are not structurally favorable and therefore do not condemn the favorable portions of the anticline. The logs of the gas wells on the crest of the anticline are not available, and the source of the gas is not known. In the test holes suggested the "Mississippi lime" should be reached at 1,775 to 1,825 feet. If these tests prove successful they would indicate that much good oil territory may be found north, west, and south of them.

The middle anticline of the Buck Creek uplift in secs. 9 and 16 has a southeastward-trending axis 1½ miles long which runs transverse to the axis of the main uplift. It has a closure of nearly 20 feet and an inclosed area of about one-third of a square mile. It is separated from the east and west anticlines of the Buck Creek uplift by synclinal reentrants which terminate in low structural saddles. An anticlinal nose trends southeastward toward the Whisky Hollow anticline and is separated from it by a low structural saddle. The effective gathering area for this anticline is limited to the long, broad synclinal reentrant on the southwest and to the smaller synclinal reentrant on the north. Structurally the southwestern portion of the anticline is more favorable for oil accumulation than the remainder of it, because this portion has a larger gathering area to supply the oil and better conditions for its accumulation. The faults above described may, however, retard the migration of oil and cause some accumulation on their west sides. An abandoned well on the crown of the fold west of the south quarter corner of sec. 9 is now making some gas. Several wells in the NW. ¼ sec. 16 are producing oil from the Bartlesville sand, and future development should extend toward the southeast from these wells. The north flank of this anticline is not unfavorable for the accumulation of oil and may show a good yield. A well is now being drilled near the west quarter corner of sec. 9, and if it proves successful oil may be expected in any direction except due east toward the bottom of the shallow syncline. If the well is a failure after penetrating the "Mississippi lime" 300 to 400 feet, another test hole should be drilled about the center of the SW. ¼ sec. 9, where the "Mississippi lime" may be expected at about 1,825 to 1,850 feet.

The east anticline in secs. 9 and 10 forms the east end of the main Buck Creek uplift, and their axes coincide. It has a closure of nearly 10 feet and its one closed contour incloses an area of about a quarter of a square mile. It is limited on the north and south by well-developed synclines and is separated from the rest of the Buck Creek uplift on the west and from the Buck Point anticline on the east by low structural saddles. Dry holes have been drilled on the south and north of this anticline, but they are in synclines or other unfavorable localities and therefore are not an index to the oil or gas possibilities of this anticline. An abandoned well on the crown of the upfold near the west quarter corner of sec. 10 is making some gas, but the source of the gas is not known. This well, however, indicates that the crest will yield gas and that the flanks may yield oil. A favorable locality for the accumulation of oil is the anticlinal nose extending northeastward into sec. 3, although a dry hole is reported at the northwest corner of sec. 10, a locality which structurally is not unfavorable. The log of this well is not available, but it does not necessarily condemn this part of the anticline. At the location for a test hole indicated on the map (Pl. XV) the "Mississippi lime" should be reached at about 1,700 to 1,725 feet.

If this well proves a success, oil may be expected to the north, west, and southwest.

Structurally the Buck Creek uplift as a whole has great oil and gas possibilities, but some of the wells already drilled are not particularly encouraging and indicate variable sand conditions as well as small production. The producing wells further indicate that there are at least three horizons at which oil or gas, or both, may be obtained—the Peru sand, the Bartlesville sand, and the top of the "Mississippi lime." This "lime," however, has not been thoroughly tested, and there may be porous beds below horizons penetrated by the drill that will yield considerable oil.

DOE CREEK DOME.

The Doe Creek dome is a sharp, roughly circular uplift with a small crown in the N. ½ sec. 3, T. 26 N., R. 11 E. An anticlinal nose trends northwestward from the crown into secs. 33 and 34, T. 27 N., R. 11 E. The dome has a closure of nearly 60 feet and an inclosed area of three-quarters of a square mile. The rocks affected by the uplift cover about 3 square miles. It is limited on the north and south by major well-developed synclines, which merge into a sharp structural saddle on the east side of the dome. That part of the dome situated in T. 26 N., R. 11 E., has not been tested, but the anticlinal nose extending into secs. 33 and 34, T. 27 N., R. 11 E., is showing a good oil production and is reported to have two gas wells, one of which is said to be abandoned. The logs of the gas wells are not available and the source of the gas is not known. Some of these oil wells are reported to have had an initial daily production of as much as 75 barrels, probably from the Bartlesville sand. The crown of the dome is likely to be gas bearing, but from structural considerations the west, north, and south flanks should yield good quantities of oil. The map (Pl. XV) shows a location for a test of this dome in sec. 3, T. 26 N., R. 11 E., where the "Mississippi lime" is believed to lie at a depth of about 1,750 to 1,800 feet and to be favorable for the production of oil and gas. If this test hole yields oil, further development should extend in all directions, but the most favorable territory lies to the south and west.

BUCK POINT ANTICLINE.

The Buck Point anticline, an irregular-shaped upfold in secs. 11 and 14, T. 26 N., R. 11 E., is a small part of the major uplift that trends southwest and embraces the Whisky Hollow anticline, the Okesa dome, and the Jones anticline. (See Pl. XV.) The Buck Point anticline has a closure of about 25 feet and an inclosed area of about three-quarters of a square mile. It is limited on the north and west by well-developed synclines. A prominent northward-pitching anticlinal nose extends for 1½ miles from the crown and terminates in a syncline which separates the Buck Point uplift from the Doe Creek dome and a long southwestward-pitching anticlinal nose from sec. 36, T. 27 N., R. 11 E. Low structural saddles separate the Buck Point anticline from the Whisky Hollow anticline and from the monocline on the northwest flank of the Panther Creek anticline. Structurally this anticline has excellent oil and gas possibilities. The north and west flanks of the anticline, between the bottom of the bordering syncline and the crest of the upfold, afford good gathering area, and the closure is sufficient to assure favorable conditions for accumulation. This anticline has been drilled and is yielding both gas and oil. The gas wells are on or near the crest and the oil wells are on the west flank. The gas is reported from the Burgess sand directly overlying the "Mississippi lime," and the oil comes from the Bartlesville sand and from the Burgess sand. Showings of oil are reported from the Peru, but there are no producing wells that obtain oil from this sand. Future development should extend the present productive area. The most favorable localities for oil wells are on the northward-pitching anticlinal nose in the W. ½ sec. 11, the westward-plunging nose in secs. 14 and 15, and the north flank of the anticline. A location for a test hole is suggested (see Pl. XV) in the SE. ¼ NW. ¼ sec. 11, where the "Mississippi lime" may be expected at about 1,750 to 1,775 feet. If this proves to be a successful oil well, further development should extend in all directions, but the most favorable territory is probably to the north and west.

WHISKY HOLLOW ANTICLINE.

The Whisky Hollow anticline is an irregular-shaped uplift which forms a small part of a larger uplift embracing the Buck Point anticline on the north and the Okesa dome and Jones anticline on the south. The axis trends northeast through secs. 21, 22, and 23, T. 26 N., R. 11 E. It has a closure of about 15 feet and an inclosed area of nearly half a square mile. It is limited on the south and east by a shallow syncline and on the northwest by a deep syncline which separates it from the Buck Creek uplift. The west flank is a long monocline which extends about 3 miles from the crest of the anticline and affords an excellent gathering area for the accumulation of oil. The west and northwest flanks are therefore the most favorable portions of the anticline for oil wells. The anticline has been drilled and is producing some oil and gas. Gas wells near the 980-foot contour indicate that the west flank of the anticline may be gas-bearing between that contour and the crest. Down the dip from the gas wells on the same flank several oil wells have been drilled, and a few of them are still producing. The gas wells and most of the oil wells receive their supply from the top of the "Mississippi lime" or near it, and the rest of the oil wells are producing from the Bartlesville sand. A dry hole was drilled, probably to the "Mississippi lime," on the south flank of the anticline in the SW. ¼ sec. 22. This test is in a structurally unfavorable position, because the south flank of the anticline has little or no gathering ground and oil or gas migrating up the west flank would be trapped in the crest of the Whisky Hollow anticline and the crown of the Okesa dome. Another dry hole in which a show of oil was reported was drilled to the "Mississippi lime" on the northwest flank of the anticline, in the SW. ¼ sec. 15. It is well down on the northwest flank of the anticline and is unfavorably located for the accumulation of oil. A location for a test hole is suggested on the map (Pl. XV). It is near the center of sec. 21, at the end of the anticlinal nose at the top of the steeply dipping monocline, where the "Mississippi lime" may be expected at a depth of about 1,650 to 1,675 feet. This hole may yield gas, but structurally it is favorable for the production of oil. If it proves a successful oil well, further development should extend toward the west and northwest.

OKESA DOME.

The Okesa dome, a small triangular uplift in sec. 28, T. 26 N., R. 11 E., is a part of the larger uplift that embraces the Buck Point, Whisky Hollow, and Jones anticlines. It has a closure of nearly 40 feet and an inclosed area of nearly one-third of a square mile. A prominent anticlinal nose pitches westward from the crown of the dome through sec. 29 and joins an anticlinal nose of the Lost Creek anticline. A broad, flat syncline borders the Okesa dome on the east, and a deep, rather broad syncline separates the dome from the Lost Creek anticline on the southwest. The rocks affected by this upfold cover about 2 square miles. A monocline extends for several miles to the west and northwest from the crown of the dome and forms an excellent gathering ground for oil. The closure, together with the anticlinal nose and the steeply dipping west flank, affords ample reservoir space for a considerable quantity of petroleum. The crown of the dome is nearly certain to yield considerable gas, but the anticlinal nose and the west and northwest flanks are structurally very favorable oil territory. No wells have yet been drilled in the inclosed area, but several oil and gas wells have been drilled on the northwest flank as low as the 930-foot contour. (See Pl. XV.) Some of the oil wells had an initial daily production as high as 20 to 30 barrels, probably from the Bartlesville sand, but no information is available regarding the source of the gas or its yield. The location for a test hole suggested on Plate XV is in the NW. ¼ sec. 28, where the "Mississippi lime" may be expected at a depth of about 1,675 to 1,700 feet. It is on the west point of the triangular dome and just below the 1,000-foot contour, or about 20 feet vertically below the crown. If this test yields gas the next well should be drilled 1,000 feet to the west. According to the structure oil may be expected on this dome in the N. ½ and the N. ½ S. ½ sec. 29, the SE. ¼ sec. 20, and the SW. ¼ sec. 21, but the NW. ¼ sec. 28, on and near the crown of the dome, is for the most part gas territory.

JONES ANTICLINE.

The Jones anticline is a small upfold which forms a part of a larger uplift that trends northeast and embraces the Okesa dome and the Whisky Hollow and Buck Point anticlines. These different crests or crowns of the major uplift are separated by narrow structural saddles. The Jones anticline has a closure of about 15 feet and an inclosed area of about one-third of a square mile. It is limited on the west by a deep syncline and on the south, east, and north by a broad, shallow syncline. The effective gathering area is limited to the west flank between the crest of the upfold and the bottom of the syncline. This anticline has been drilled and has a number of producing wells. Several wells are producing gas on the crest of the anticline, but the source of the gas is not known. The oil wells on the west flank obtain their oil from the Bartlesville sand. Some of these had an initial daily production of as much as 40 barrels and are now yielding from 3 to 5 barrels. Several dry holes adjacent to the oil wells are reported and indicate variable sand conditions. Structurally most of the W. ½ sec. 33 is favorable oil territory except along the west and south lines of the section. Further development for oil should be extended south and east from the present producing wells. Several dry holes on the east flank of the anticline substantiate the rule that in general little or no production may be expected from the east flanks of anticlines in this area. The crest will probably yield gas from any petroleum-bearing bed, but structurally the west flank is favorable for obtaining oil from the Bartlesville sand and probably from the "Mississippi lime," which on the crest may be expected at a depth of about 1,900 feet.

PHILLIPS ANTICLINE.

The Phillips anticline is an elongated uplift with northward-trending axis mainly in the northeast corner of T. 25 N., R. 11 E., and is described by Hopkins.[1] Two domes occur along the anticlinal axis.

[1] Hopkins, O. B., report on T. 25 N., Rs. 11 and 12 E.: U. S. Geol. Survey Bull. 686–H, 1918.

The north dome extends into T. 26 N., R. 11 E., where anticlinal noses pitch north and west into secs. 35 and 36. The crown of the north dome in sec. 1, T. 25 N., R. 11 E., has a closure of about 20 feet and the lowest closed contour (1,150-foot) incloses about a quarter of a square mile, 15 acres of which is in sec. 36, T. 26 N., R. 11 E. A well-developed syncline borders it on the east, and it is separated from the Panther Creek anticline on the northeast by a narrow, shallow syncline which plunges westward through secs. 36, 35, and 26. A steeply dipping monocline extends westward from the crest of the anticline for about 2 miles, ending in a broad, shallow syncline, and affords an excellent gathering area for the accumulation of oil. Several holes have been drilled on this anticline, and some of them are reported to have been failures. Three dry holes are reported on the north flank. These are favorably located structurally, but the records are not available and therefore they may not constitute real tests. Another hole near the southeast corner of sec. 36, T. 26 N., R. 11 E., was drilled to the Bartlesville sand. Conflicting reports are given for the results of this well; some say it is a gas well with a show of oil and some an oil well with a show of gas. It is on the northeast flank of the anticline and near the bordering syncline and is therefore not so favorably located as the dry holes above mentioned. Several wells are producing gas from the crown of the north dome of the Phillips anticline, in the N. ½ sec. 1, T. 25 N., R. 11 E., but the logs are not available and therefore the source of the gas is not known. A location for a test hole for oil is suggested on the west flank (see Pl. XV), between the 1,120 and 1,130 foot contours, where the "Mississippi lime" may be expected at a depth of about 1,775 feet or more. If this well yields oil, further development should extend west and north as well as east.

PANTHER CREEK ANTICLINE.

The Panther Creek anticline is an elongated upfold with northward-trending axis which roughly parallels the township line between Rs. 11 and 12 E. (See fig. 21.) The crest lies east of the township line and has four small domes. Each of the southern two domes has a closure of about 15 feet and an inclosed area of about 40 acres, and each of the northern two has a closure of less than 10 feet and an inclosed area of about 50 acres. These domes are separated from one another by shallow structural saddles across which the productive area will probably be continuous. The major anticline exclusive of the southernmost dome has a closure of about 30 feet and an inclosed area of about 1½ square miles. The Panther Creek anticline is separated from the Phillips anticline on the south by a narrow structural saddle. The axis of an anticlinal nose pitches northeastward from the crest of the uplift into the alluvial valley of Sand Creek, in sec. 7, T. 26 N., R. 12 E. A monocline extends 1½ to 2 miles west from the crest and affords an excellent gathering ground for the accumulation of oil. This uplift has been tested by drilling and is now yielding good quantities of oil and gas. The crowns of two northern domes of the anticline and their west flanks down as far as the 1,100-foot contour (see map, Pl. XV) are almost completely drilled. The oil produced comes from the Bartlesville sand, and some of the wells had an initial daily production as high as 300 barrels. The southern domes are not so largely drilled, but several wells on them are producing oil and gas. Here the oil comes from the Bartlesville sand and the gas from the top of the "Mississippi lime." The west flank of the main uplift is yielding gas from the "Mississippi lime" in secs. 13, 24, and 25 between the 1,110-foot and 1,050-foot contours. This indicates one of a number of conditions: (1) That the "Mississippi lime" on the crest of this anticline will probably yield high-pressure gas; (2) that the structure of the "Mississippi lime" in this vicinity does not conform to the surface structure, which is not likely because the oil wells indicate that the structure of the Bartlesville sand conforms with the surface structure; (3) that the gas-bearing stratum varies in porosity, being closely cemented high on the anticline and thus trapping the gas well down on the west flank; or (4) that the gas may have been trapped by a terrace in the unexposed rocks which is not shown by the surface rocks. The evidence seems to indicate that the "Mississippi lime" on the crest of the Panther Creek anticline and its west flank between the crest and the present gas wells will yield considerable gas. The "Mississippi lime" should be reached on the crest of the anticline at depths of about 1,725 to 1,775 feet.

AREAS OF UNFAVORABLE STRUCTURE.

Experience in drilling and developing oil lands in Osage County has shown that oil and gas production is confined to the major uplifts and that the major synclines or depressions yield no oil or gas. Several localities are known, however, where oil is obtained in an area of synclinal structure, but such a depression is usually an integral part of a major uplift. The list below is intended to point out the localities in this area which on the basis of the surface structure alone appears to have little or no chance of yielding oil. The greater part of these localities will probably be barren, though exceptions due to variations in sand conditions, lack of parallelism in the strata, or some other cause may be found. The lands in the area covered by this report which are unfavorable for the accumulation of oil because they are situated in or near the bottoms of major, well-developed synclines are as follows (see Pls. XIII–XV and fig. 22):

T. 26 N., R. 9 E.:
- Sec. 6, N. ½ and SE. ¼.
- Sec. 12, NE. ¼.
- Sec. 24, E. ½.
- Sec. 35, E. ½.

T. 26 N., R. 10 E.:
- Sec. 6, SW. ¼.
- Sec. 12, NE. ¼ and SW. ¼.
- Sec. 18, S. ½ S. ½.
- Sec. 19, NW. ¼.
- Sec. 20, W. ½.
- Sec. 29, N. ½.
- Sec. 31 E. ½.
- Sec. 32, S. ½ and S. ½ N. ½.

T. 26 N., R. 11 E.:
- Sec. 1, SW. ¼.
- Sec. 2, SE. ¼ and NW. ¼.
- Sec. 3, SE. ¼.
- Sec. 4, N. ½.
- Sec. 5, NW. ¼.
- Sec. 6, S. ½.
- Sec. 15, NW. ¼.
- Sec. 16, E. ½ NE. ¼.
- Sec. 19, N. ½.
- Sec. 23, SW. ¼ and NE. ¼.
- Sec. 27, SE. ¼.
- Sec. 32, N. ½ and SE. ¼.
- Sec. 34, W. ½ and NE. ¼.

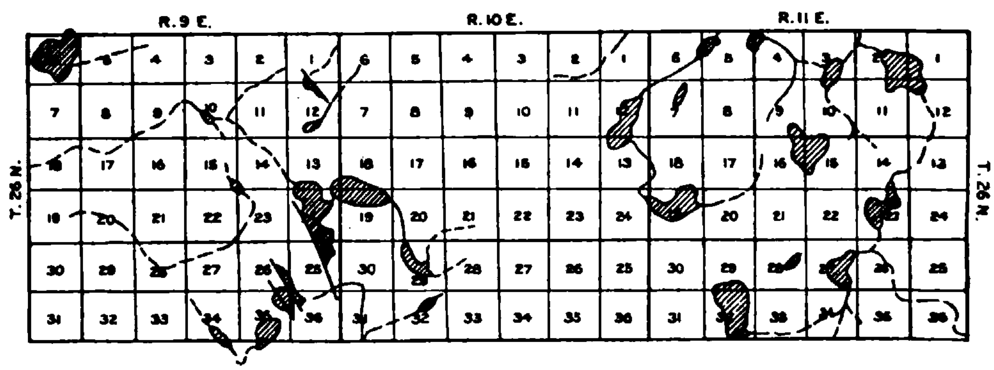

FIGURE 22.—Sketch showing roughly the position of synclinal axes in T. 26 N., Rs. 9, 10 and 11 E., shaded to indicate areas within closed contours.

T. 20 N., R. 11 E.

By E. Russell Lloyd and Kirtley F. Mather.

INTRODUCTION.

T. 20 N., R. 11 E., lies in the southeastern part of the Osage Reservation, in the Hominy quadrangle. (See fig. 1.) There is no town or railroad in the area, but Sand Springs, on the Missouri, Kansas & Texas Railway, is only a mile from the south border, and the southeast corner of the township is 4 miles from Tulsa. The township is mostly rugged and has a maximum relief of about 400 feet. Roads are poor, and only a small part of the township is cultivated.

The field work in this township was done in July and August, 1918, by the writers, assisted by C. R. Bickel and M. G. Gulley, instrument men. The area mapped by each geologist is shown by the diagram inserted on Plate XVIII. The whole area was mapped with plane table and telescope alidade.

STRATIGRAPHY.

ROCKS EXPOSED.

GENERAL CHARACTER.

The rocks exposed in T. 20 N., R. 11 E., are of middle Pennsylvanian age and comprise from 650 to 750 feet of sandstone, shale, and limestone. The character and succession of the beds of the upper 350 feet of the series are shown graphically in figure 23. Shale constitutes by far the larger part of the exposed rocks, although the sandstone beds are most prominent. The three beds of limestone form only a minor part of the section.

KEY BEDS.

For the convenience of those wishing to do geologic work in the township, a few of the most important or key beds will be described in detail.

Avant limestone.—The Avant limestone is the more conspicuous and the higher of the two limestones present in the western part of

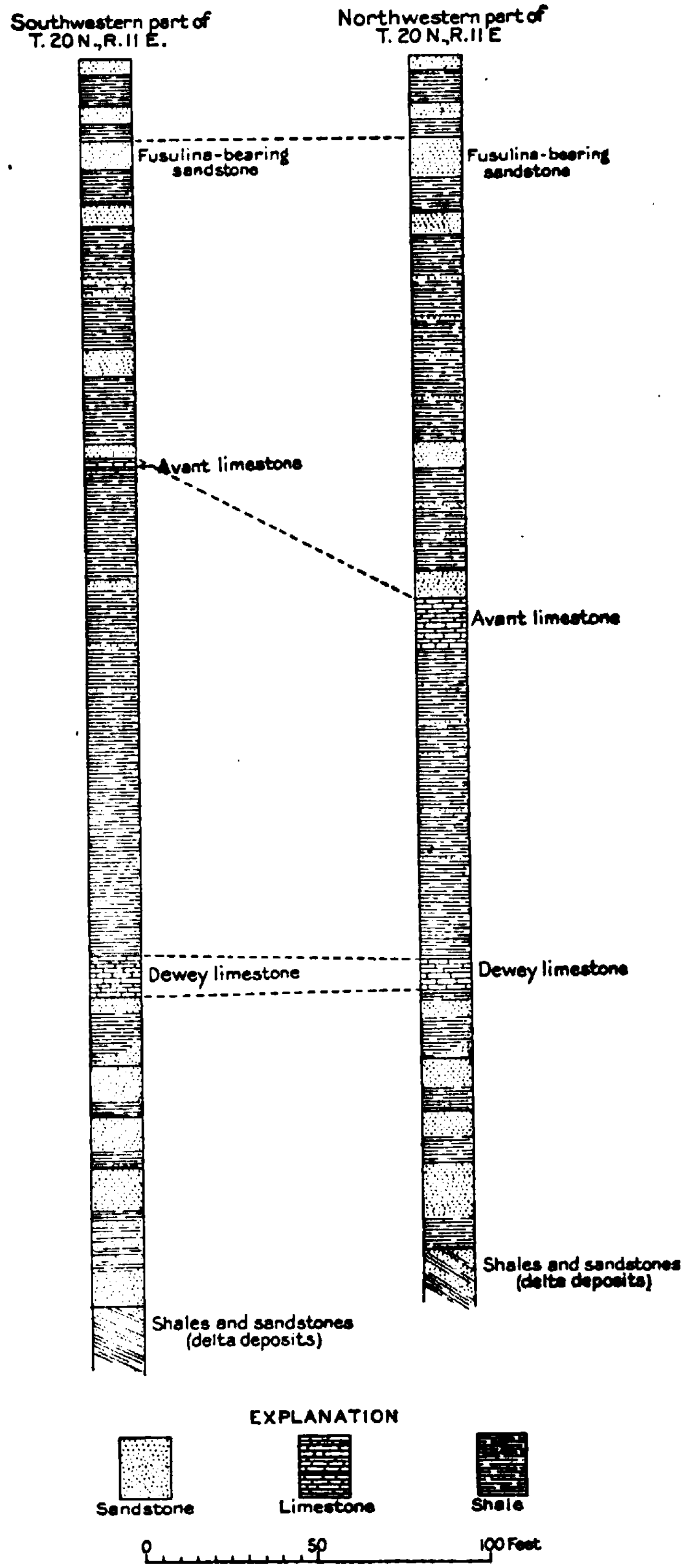

Figure 23.—Stratigraphic sections of rocks exposed above the delta deposits in T. 20 N., R. 11. E.

T. 20 N., R. 11 E. It is extremely variable in thickness and in composition, but generally appears as a hard ledge forming a low cliff and bench along the hillsides in the northwestern part of the township. On wooded slopes, however, it may be entirely hidden beneath talus, soil, and vegetation for considerable distances along its outcrop. Its weathered surface is nearly everywhere a shade of brownish red, although certain beds within it are gray in some localities. The color on fresh fracture is ordinarily purplish gray, although this characteristic is also rather variable.

The limestone is sandy, incloses lenses of shale, and is notably crossbedded where exposed near the middle of the west side of the township but is much more free from impurities farther north, where it is commonly very dense, fine grained, and hard. Crinoid stems are numerous in it everywhere, and a varied fauna is present in some places. Its thickness ranges between 5 and 15 feet, decreasing irregularly from north to south.

At the north margin of the township the vertical distance between the Avant and Dewey limestones is approximately 105 feet. This interval increases toward the south and reaches a maximum of 145 feet in sec. 20. A corresponding southward convergence of the strata above the Avant is also of considerable importance in detailed mapping. In sec. 18 there is a sandstone bed, thickly crowded with fossil *Fusulina*, 86 feet above the Avant. Toward the north this interval increases until, in sec. 5, this *Fusulina*-bearing sandstone is 135 feet above the Avant. These two convergences so nearly compensate each other that the *Fusulina*-bearing sandstone is approximately parallel with the Dewey limestone, although neither is parallel with the intermediate Avant limestone in this township. The outcrop of the Avant is shown on the map (Pl. XVIII).

Dewey limestone.—The Dewey limestone is coarse grained, massive, and highly fossiliferous and consists of alternating bands of gray and brownish-red limestone. ' It crops out at the foot of the same escarpment as the Avant, but the exposures are not continuous, being in many places concealed by a soil mantle. The Dewey limestone has a maximum thickness of about 12 feet, is immediately overlain by a thick shale, and grades downward into a highly ferruginous nonresistant sandstone. The outcrop of the Dewey is not shown on the map.

Sandstone benches below Dewey limestone.—Immediately below the Dewey limestone and associated ferruginous sandstone is a group of sandstone beds with a total thickness of 75 feet or more. The higher beds of this group are flaggy, the lower part massive. The topmost bench, which is 12 to 15 feet below the top of the Dewey limestone, caps the higher hills in the central part of the township east of Shell Creek. West of Shell Creek this upper sandstone bed is fossiliferous, but throughout the greater part of the area no fossils were found. In a few places the overlying ferruginous sandstone is preserved, l for the most part the horizon can be recognized only by the fact th this is the highest sandstone east of the Dewey-Avant escarpment ar by the interval to the next underlying bench.

The second distinctive bench below the Dewey, 20 feet below th top bench, is formed by a typically massive sandstone and is in mos places readily recognizable. Another prominent bench marking th top of a lower sandstone of the group is 50 feet below the top bench This sandstone also is a typically massive sandstone and in the southern part of the township is separated by shale from the massive sandstone above it. The horizon of the top bench in the northern part of the township and the top of the lower bench in the southern part are shown on the map (Pl. XVIII).

Shales and sandstones (delta deposits) above Hogshooter limestone.—Below the group of sandstones described above is a thick series of shale and sandstone which was deposited in the delta of a northward-flowing stream. The series consists in greater part of shale but includes a number of very prominent massive sandstone beds which are, however, very lenticular and, at least for the most part are foreset delta deposits. These deposits are well exposed in th valleys of Turkey and Blackboy creeks and in the hills to the east The deltaic origin of the rocks is shown by the lenticularity of th sandstone beds and by their generally northward dips, which do n correspond with the structure of overlying and underlying rocks.

There is evidence of a very marked decrease in the thickness these delta deposits from south to north. The logs of the wells secs. 23 and 24 show that the interval between the Dewey a Hogshooter is 400 to 410 feet. In sec. 10 the interval is a little l about 375 feet. In T. 21 N., Rs. 11 and 12 E., however, the cor sponding interval is not over 260 feet. The sandstone beds of t series were studied and contoured in as much detail as exposures wo permit and proved to be absolutely valueless for determining underground structures. No structure contours, therefore, are sh in the area where these beds crop out.

Hogshooter limestone.—The Hogshooter limestone crops out in valley of Blackboy Creek in sec. 36. In this area it is a promir bed, 12 to 20 feet thick, alternating gray and brick-red in color, t bedded, and highly fossiliferous. The uppermost foot or two is co posed largely of crinoid stems and contains numerous cup corals.

ROCKS NOT EXPOSED.

A study of well logs shows sandstone, shale, and limestone betwee the surface beds and the productive oil and gas zones, with a grea preponderance of shale. The wells of which detailed logs are avai

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able lie in the eastern part of the township, and of these logs four have been selected to show the succession of beds below the surface. (See Pl. XIX.)

The Hogshooter limestone in each of the wells of which the logs are shown on Plate XIX lies between 300 and 400 feet below the surface. The first easily recognizable bed below the Hogshooter is a limestone 20 to 50 feet thick, usually called the Big lime by the drillers. It lies from 730 to 760 feet below the Hogshooter, and the intervening rocks consist very largely of shale with thin beds of limestone and some sandstone; the sandstone is more prominent toward the south. Below the Big lime is 130 to 150 feet of shale and then the "Oswego lime" of the drillers, which is 40 to 50 feet thick.

Below the "Oswego" is a series of shale with thin beds of sandstone and limestone 300 to 400 feet thick, below which in turn is the series of sandstone beds that include the productive oil and gas zones of the district.

The top of the productive sandy series lies 1,300 to 1,400 feet below the Hogshooter limestone. The interval to the Avant limestone is more variable because of the variation in thickness of the delta deposits described above and also because of the convergence between the Dewey and Avant limestones.

In the eastern part of the Osage country gas is commonly encountered in the upper part of the group of sands, and in places the gas sand is separated from the underlying oil-bearing sands by a varying interval of shale, but elsewhere the sands are continuous. East of this area, in Tps. 20 and 21 N., R. 12 E., the oil-bearing sands aggregate 50 to 160 feet in thickness.

Any sand productive of oil in this zone is commonly called the Bartlesville sand, but it may not be the same as the productive sand at Bartlesville. There the productive sands lie about 1,350 feet below the top of the Avant. In the Avant district these sands lie from 1,360 to 1,440 feet below the top of the Avant limestone.[1] Thence southward the interval gradually increases, and in the southern part of T. 20 N., R. 11 E., it is about 1,750 feet.

So far no oil has been found in the Bartlesville sand in this township, the production being obtained from a thin sand about 300 feet below the top of the Bartlesville, commonly known as the Burgess sand. This sand, which is only a few feet thick, rests immediately on a massive limestone series which is called the "Mississippi lime." One well (No. 23 in sec. 23; see Pl. XIX) has been drilled 450 feet into the "Mississippi lime," disclosing two beds of sandstone. Elsewhere in the Osage country sandstone beds in the "Mississippi lime" have been productive of oil, and no anticline or dome in this town-

[1] Emery, W. B., U. S. Geol. Survey Bull. 686, p. 4, 1918 (Bull. 686–B).

ship should be considered thoroughly tested until a well has been drilled at least 400 feet into the "Mississippi lime." The well in sec. 23 is not favorably situated with regard to structure and probably for this reason found no oil.

STRUCTURAL FEATURES.

AREAS OF FAVORABLE STRUCTURE.

This township is a part of a large region where the general dip is westerly or northwesterly. The presence of an easterly dip is therefore significant, for it indicates an upfold which may yield commercial quantities of oil. The general westerly dip is accentuated in a zone 1 to 1½ miles wide extending across the central part of the township from northeast to southwest. East of this is a zone of open structure with two and possibly three folds that are very favorable for the accumulation of oil and also two or more which are smaller. The structure of the eastern tier of sections is undetermined. In the northwestern part of the township the general westerly dip is continued with small irregularities, one of which may be of sufficient extent to serve as an oil reservoir. There is a little faulting in the western part, but none in the remainder of the township.

The structure is shown on the map (Pl. XVIII) by 10-foot structure contours, which are based solely on surface data and are drawn on a theoretical bed 400 feet below the top of the Dewey limestone. The steep westerly dip shown in secs. 25 and 36 by dashed contours is based on the Hogshooter limestone, the interval from the Hogshooter to the Dewey being undetermined on account of the presence of the delta deposits. The structure mapping based on the Hogshooter is not correlated with that based on the higher beds.

The two most prominent upfolds in the township and the most promising for oil lie at the east border of the region of steep westerly dip. The northern one is near the head of the westerly branch of Turkey Creek, in secs. 10, 11, 14, and 15, and is called the Turkey Creek dome. The southern one, in secs. 21, 22, 27, and 28, is near Wimberley School and is called the Wimberley dome. Both lie along the same anticlinal axis and have a gathering ground extending to the west for at least 3 or 4 miles.

The crest of the Turkey Creek anticline in the eastern part of secs. 10 and 15 is outlined by the 570-foot contour. The 560-foot contour almost surrounds the fold but does not close on the south. This contour also outlines a small syncline east of the dome in secs. 11 and 14. A much smaller dome, really a part of the larger one, is outlined by the 570-foot contour in the southeastern part of sec. 15. The dip on the west side of the Turkey Creek dome is comparatively steep, but that on the east side is very gentle. The probably productive area lies northwest, west, and southwest of the crest of the dome, the gently dipping east flank being less promising. A productive well recently drilled in the SE. ¼ NE. ¼ sec. 10, approximately on the 530-foot contour, some distance down on the northwest flank, is particularly promising for future wells drilled farther south on this dome.

The Wimberley dome is in most aspects very similar to the Turkey Creek dome. It is kidney shaped in outline, and the highest part is at the north, nearly at the corner of secs. 21, 22, 27, and 28. The greater part of the favorable structure occurs in sec. 28. The highest contour is the 580-foot, and the lowest one to close is the 570-foot contour. The 560-foot contour outlines the dome but does not close on the northeast. This contour partly incloses a shallow syncline east of the dome, extending in a northeasterly direction approximately along the valley of Euchee Creek. No wells have been drilled on this dome, the nearest one being a dry hole on Euchee Creek in the NE. ¼ sec. 33, at the bottom of the syncline on the east. The area of probably productive territory is considerably larger in the Wimberley dome than in the Turkey Creek dome and extends along the west flank of the dome from a point near the center of sec. 21 southward across sec. 28. Two very favorable localities for a test well are shown on the map (Pl. XVIII)—one on the west flank of the north end of the dome, near the south line of sec. 21, and the other on the west flank of the south end, in the SW. ¼ sec. 28. The crest of the dome is more likely to produce gas, and the east flank is unpromising.

The alinement of the Wimberley and Turkey Creek domes strongly suggests the probability of a similar uplift in the northeastern part of the township, in the valley of Turkey Creek. The structure in this area, however, could not be contoured on account of the irregularities in dip of the delta deposits which crop out there.

A small terrace in the eastern part of sec. 23 and the western part of sec. 24 has been proved by three productive wells. This terrace lies on the ridge extending eastward from the Greer farm in sec. 23, and could be only partly mapped on account of the presence of the delta deposits. It is outlined by the 630-foot contour, but the well drilled in the SE. ¼ sec. 23 shows that oil in commercial amounts may be expected as far west as the 620-foot contour. In the western part of sec. 23 there is a slight easterly dip, but not enough to make a closed contour. East of the center of this section the normal westerly dip is resumed. The extent of the potentially productive area toward the north can only be conjectured, because the surface in that direction is occupied by the delta deposits, on which structure contours can not be drawn.

The steep westerly dip west of the Wimberley and Turkey Creek line of anticlinal structure is interrupted by a small dome in sec. 29, from which a long nose extends westward across sec. 30. On this dome the 500-foot contour is the only one that is closed. The probably productive area lies in the central and western parts of sec. 29 and extends westward through sec. 30. The area has not been tested, and favorable localities for test wells are shown on the map (Pl. XVIII)—one on the northwest flank of the dome, north of the center of sec. 29, and another on the westerly nose, near the center of sec. 30. A terrace which lies mostly outside the Osage Reservation extends northwestward into the SE. ¼ sec. 31 and the SW. ¼ sec. 32. The extent of this terrace toward the south has not been mapped. The most favorable locality for a test well on that part of it which lies within the Osage Reservation is in the southeast corner of sec. 31.

Most of the northwestern part of the township has a general westerly dip, with small irregularities which in general are not suggestive of valuable oil territory. One exception is a terrace that lies mostly in the SE. ¼ sec. 5 and is outlined by the 370-foot contour. The probably productive area lies on the west flank of the terrace, in the SW. ¼ sec. 5 and the NW. ¼ sec. 8. A long nose extends westward from this terrace, the northern part of which has been cut off by a fault. A favorable locality for a test well is on the west flank of the terrace, near the south line of sec. 5.

AREAS OF UNFAVORABLE STRUCTURE.

Eastern Osage districts that have been thoroughly prospected show that accumulations of oil occur generally on the western flanks of the anticlines, domes, and terraces, extending from points near the crest down the flank. The crest of a fold is more commonly gas territory, and the east flank is generally unproductive. The shallow syncline east of the Turkey Creek and Wimberley domes may therefore be considered as probably offering unfavorable structure. Similarly a region of moderate uninterrupted westerly dip is generally unproductive. The area from Euchee Creek eastward to the ridge running north from Sand Springs and much of the northwestern part of the township, with the exception of the terrace previously described, have structure of this type and are therefore unpromising. The two dry holes shown on the map, in secs. 32 and 33, are probably in as unfavorable locations as could be selected in the township.

SAND CONDITIONS.

Very little is known of the sand conditions in T. 20 N., R. 11 E., but this very important factor in the accumulation of oil and gas must not be overlooked. Farther east the productive sands are known to be irregular both in thickness and texture. Little detailed study of sand conditions in Osage County has been made by the Survey, and only generalized statements can be presented. In a region of general dip in one direction the thinning out of an oil-bearing sand or a marked decrease in porosity in a direction opposite to the dip may have as much influence on the accumulation of oil as the structure. Thus the effect of the structure may be counteracted, making areas of apparently good structure unproductive and causing accumulation where the attitude of the strata is not itself conducive to the accumulation of oil. However, the oil in this region does not occur in a single sand but in a number of sands extending through a series several hundred feet in thickness, and it is improbable that in any anticlinal fold in this township unfavorable conditions affect all the sands.

T. 27 N., R. 7 E.

By K. C. HEALD.

INTRODUCTION.

T. 27 N., R. 7 E., is in the southeast corner of the Foraker quadrangle, Osage County. (See fig. 1.) This area was mapped by the writer in 1915, and the geologic structure was described in a paper published by the U. S. Geological Survey in 1916.[1] Subsequent work near the margin of this area revealed the necessity of some revision, and during June, 1918, a few days were spent in procuring data to make the necessary changes. The revision was confined to territory near the south boundary of the township.

It may be noted that the structure contours along the south edge of this area as shown on Plate XX do not exactly join with those in the northeast corner of T. 26 N., R. 7 E., as shown on the map in Bulletin 686–L. This discrepancy is not due to either observational error or difference of opinion concerning the contouring, but rather to the fact that the elevations on which the contouring for Plate XX is based were referred to the Foraker limestone as a datum, and those which control the contouring in Bulletin 686–L were referred to a much lower horizon. Because of convergence the two datum planes are not exactly parallel, and hence the contours show the slight discrepancy mentioned above.

STRATIGRAPHY.

EXPOSED STRATA.

The exposed rocks in T. 27 N., R. 7 E., include shales, limestones, and sandstones of upper Pennsylvanian age. Shales predominate, but the prominent outcrops of the limestones make them by far the most noticeable. The sandstones are very inconspicuous except in the southeast corner of the township. The general character and relation of the beds are shown graphically in the stratigraphic section

[1] Heald, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey Bull. 641, pp. 17–47, 1916.

(fig. 24). The characteristics of a few of the beds that were particularly helpful in determining the structure are given in detail below.

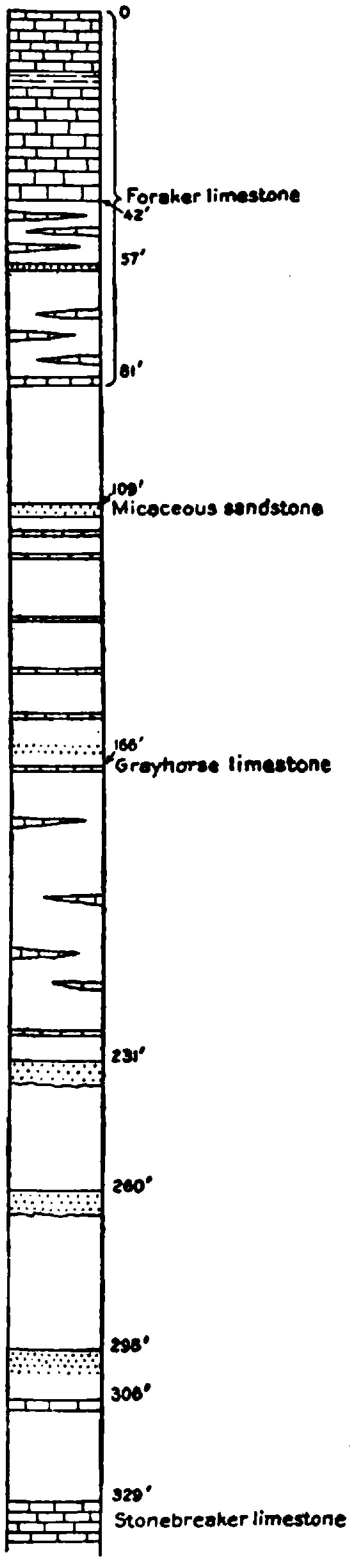


FIGURE 24.—Stratigraphic section showing rocks exposed in T. 27 N., R. 7 E.

Foraker limestone.—The Foraker limestone is made up of a series of limestone beds with thin intervening beds of shales and a few local lentils of sandstone. The total thickness of the formation in this township is about 80 feet. The limestones are massive, dense, hard, fossiliferous, and cherty and show a weathered surface of light gray to seal-brown. Most of the chert is reddish on the weathered surface and pigeon-blue on the fresh surface and carries an abundance of fossil *Fusulina*, which are dull white to yellowish white. In one bed about 26 feet below the top of the formation most of the chert is decomposed and presents a peculiar porous appearance. This characteristic made the bed which carries this decomposed chert of particular assistance in determining the geologic structure. The Foraker limestone covers a large part of T. 27 N., R. 7 E., and much of the structure has been determined from elevations taken on one or another of its constituent beds.

Micaceous sandstone.—A micaceous sandstone about 28 feet below the base of the Foraker limestone was used in determining the structure over a part of this township. It is a particularly good horizon marker, as there is no other sandstone with which it might possibly be confused for a considerable distance either above or below it. In the southern part of the township there are lentils of sandstone not far from the outcrop of the micaceous sandstone, but the lithologic character of the micaceous sandstone is so distinctive that there is small chance of miscorrelation. It has a reddish-gray weathered surface and a fresh surface of slightly lighter color thickly dotted with brown spots. Its most distinctive feature is the presence of muscovite, which in many localities is very prominent and which can always be detected if the rock is carefully examined.

The sandstone is well exposed on the hill near the center of sec. 14, T. 27 N., R. 7 E., where it crops out some distance below the top of the hill. The sandstone that caps the hill is a lentil in the Foraker limestone above the micaceous sandstone.

Stonebreaker limestone.—The Stonebreaker limestone was used as the key bed in determining the shape and size of the anticline in the extreme southeast corner of T. 27 N., R. 7 E. In that locality it is about 250 feet below the base of the Foraker limestone. It is 16 feet thick and consists of a series of thin limestone beds with intervening shales. The limestone is hard, tough, and sparingly fossiliferous. The most abundant fossils are small *Fusulina*, but one bed also carries many Cryptozoa, most of which have a fragment of a bryozoan as a nucleus. The weathered surface is light gray with many blotches of limonite-yellow. This limestone has been described more fully by the writer in another paper.[1]

PENNSYLVANIAN ROCKS NOT EXPOSED.

Below the surface there is a series of about 2,500 feet of Pennsylvanian rocks resting upon the Mississippian limestones. The exact horizon where the Pennsylvanian rocks stop and the Mississippian rocks begin has not been determined, although it is known that the limestone called the "Mississippi lime" by drillers is very near the top of the Mississippian series. The general sequence of the beds is shown graphically in Plate XX.

SANDS CARRYING OIL OR GAS.

No drilling has been done in T. 27 N., R. 7 E., but some idea of the approximate position of the gas or oil bearing beds underlying this township may be gained by a study of the records of the wells in the Pearsons Switch gas and oil field, which lies less than a mile east of the eastern boundary of the township. The assumption that the oil and gas bearing sands of the Pearsons Switch field underlie the township to the west is justified by the facts that the higher beds have been recognized in the Mayers gas field, 5 miles to the southeast, which shows that they have a considerable extent, and that the bed which carries the oil at Pearsons Switch is believed to be the "Mississippi lime" which is recognized in wells in many parts of the Osage Reservation and which is probably the most widespread oil and gas bearing bed in this general region.

Most of the gas in the Pearsons Switch field comes from a series of six sands, the highest of which is about 630 feet below the Stonebreaker limestone and the lowest about 420 feet lower. Below these sands there is a series about 600 feet thick of barren shales and sandstones, and next a sand about 30 feet thick which is reported to carry

[1] Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 63–64, 1918 (Bull. 691–C).

gas but from which no gas has ever been utilized. Below this bed no oil or gas bearing sands have been reported, but a bed of limestone, which is probably the Fort Scott ("Oswego") limestone, about 2,100 feet below the Stonebreaker limestone carries gas and has given a showing of oil. About 400 feet deeper the top beds of the "Mississippi lime" carry both oil and gas. Although only a single well has been drilled to the "Mississippi lime" in the Pearsons Switch field, its initial flow of 400 barrels a day amply justifies a recommendation that wells be bored to this horizon on all the pronounced anticlinal folds in this general region.

The beds below the top of the "Mississippi lime" have not been reached by any of the wells that have been drilled within a few miles of T. 27 N., R. 7 E., so it is impossible to state whether or not these beds contain oil or gas. However, it is known that elsewhere in the Osage Reservation beds from 100 to 300 feet below the top of the "Mississippi lime" carry oil and gas, and tests in T. 27 N., R. 7 E., must reach these horizons to be adequate.

STRUCTURE.

GENERAL FEATURES.

The rocks in T. 27 N., R. 7 E., have an average westerly dip of about 33 feet to the mile. The beds do not slope uniformly but form series of alternating "steeps" in which the westerly dip may be as great as 120 feet to the mile and "flats" in which the rocks may even slope to the east for a short distance.

The axes of the anticlines and domes which modify the general structure are shown in figure 25.

ANTICLINES, DOMES, AND TERRACES.

DUGOUT CREEK ANTICLINE.

The axis of the Dugout Creek anticline trends southwestward from the northwest corner of sec. 9 to the southwest corner of sec. 18. (See fig. 25.) It is a gentle fold that plunges to the west with no reversal of the westerly dip except for a very small domelike bulge in the east-central part of sec. 18, which is probably too insignificant to have any effect on the tendency of the structure to bring about an accumulation of oil or gas. Folds of this general type have not been found very productive elsewhere in the Osage Reservation, although small oil and gas wells have been developed on some of them. It is recommended that no test holes be drilled on this anticline unless some of the structurally more favorable areas near by yield either oil or gas in quantity. If a well is sunk on this anticline a good location should be near the SE. ¼ SE. ¼ sec. 7.

NORTH BIRD CREEK ANTICLINE.

The axis of the North Bird Creek anticline extends from the NE. ¼ sec. 11 to a point near the center of the NW. ¼ sec. 20. (See fig. 25.) The fold is long and relatively narrow, and the rocks along the axis plunge westward with no hint of a reversal of dip. On the flanks of the fold the beds dip rather steeply to the northwest and southeast; and on the tip in sec. 20 there is a very pronounced westerly dip.

Although this is a prominent fold the absence of any closure or dip to the east makes it seem rather improbable that it has been effective in producing the formation of a large pool of either oil or gas. However, it is certainly better suited to have brought about such an accumulation than the territory immediately to the north or south of it; accordingly, if any area near by whose structure appears more favorable yields gas or petroleum, it will be perfectly justifiable to make careful tests of this fold. Good locations for such tests are the SW. ¼ SW. ¼ sec. 11 and extreme southwest corner of sec. 15. A test might also be made in the E. ½ sec. 20. If oil or gas is not found in the shallow sands which are productive at Pearsons Switch and should here lie between 950 and 1,450 feet below the surface, the wells should be deepened to the "Mississippi lime" and should not be abandoned until a depth of at least 3,000 feet is attained, unless oil or gas is encountered at shallower depth.

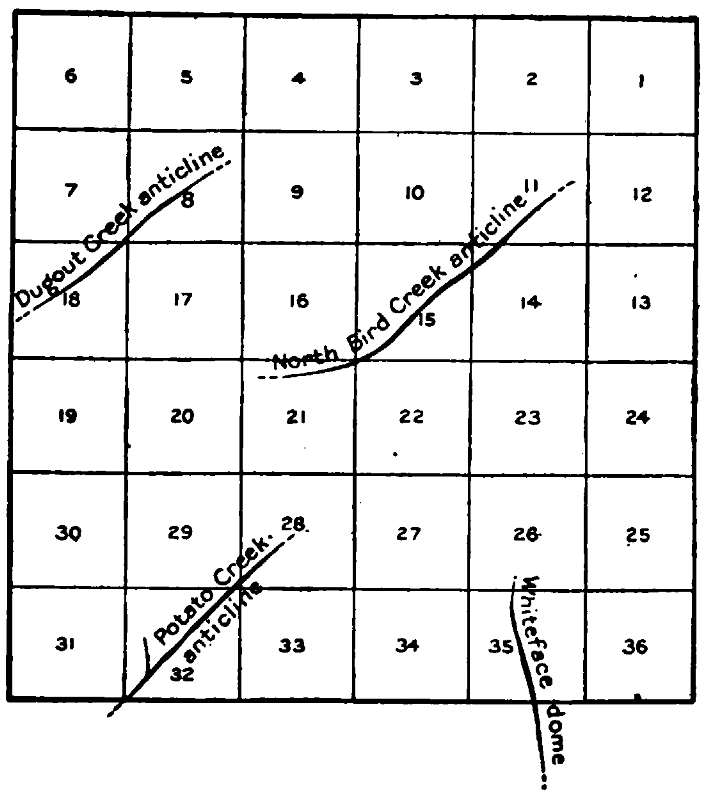


FIGURE 25.—Sketch showing approximate positions of axes of anticlinal folds in T. 27 N., R. 7 E.

POTATO CREEK ANTICLINE.

The axis of the Potato Creek anticline extends from a point near the southwest corner of sec. 32 to the middle of sec. 28, T. 27 N., R. 7 E. (See fig. 25.) On this axis there are two minor domelike bulges—one in the SW. ¼ sec. 32, the other in the SW. ¼ sec. 28—so that the top of the anticline has a sway-backed profile, being highest near the ends. The dome in the SW. ¼ sec. 32 is more pronounced and has a closure of about 15 feet. The closure on the dome in sec. 28 is probably a little less than 10 feet.

In spite of its small closure this anticline should be effective in stopping the migration of oil or gas, and if these substances are present at all in this region they should be found below this fold. Dips on all sides of the fold are pronounced, and any oil or gas moving up the dip would have to traverse the length of the anticline and pass through a very narrow neck at the north end of the fold to escape toward the northeast. The area which may be favorably affected by the structural conditions on this fold exceeds 2 square miles.

No drilling has been done nearer this fold than the Pearsons Switch field, which is some 7 miles distant, so that it is impossible to do more than guess at the conditions below the surface at this locality. If the productive sands of the Pearsons Switch field are present here, a well drilled on the top of the highest point of the fold in the SW. ¼ sec. 32 should encounter gas sands between 1,000 and 1,400 feet below the surface. The Fort Scott limestone should lie at a depth of about 2,360 feet, and the oil-bearing bed on the top of the "Mississippi lime" at about 2,800 feet.

Good locations for test wells on the Potato Creek anticline are near the center of the SW. ¼ SW. ¼ sec. 32 and in the extreme southeast corner of sec. 29. The wells should be bored at least 3,000 feet unless oil or gas in paying quantity is found at a shallower depth.

WHITEFACE DOME.

The crown of the Whiteface dome lies in the SE. ¼ sec. 35, and the flanks of the dome cover most of sec. 35 and the SW. ¼ sec. 36, T. 27 N., R. 7 E., and most of sec. 2, T. 26 N., R. 7 E. (See fig. 25 and Pl. XX.) This is a pronounced fold with a closure of about 25 feet and it may influence the accumulation of oil or gas over 2 square miles or more.

The Whiteface dome is but 3 miles from the Pearsons Switch anticline, which is known to contain large volumes of gas and oil. The closure of the Whiteface dome is almost as great as that of the Pearsons Switch anticline, and the areas covered by the two folds are about the same. Accordingly it seems reasonable to believe that this dome will yield both gas and oil. There is ample gathering ground to the northwest, west, and south of the dome, and from this gathering ground the oil and gas may be expected to travel up the steep westerly dip and collect under the crown of the dome and on its flanks. The shallow sands that yield gas in the Pearsons Switch field should underlie the crown of the Whiteface dome at a depth of 680 to 1,200 feet. The Fort Scott limestone should be encountered at a little more than 2,100 feet, and the top of the "Mississippi lime" at about 2,500 feet. Besides the sands mentioned there may also be productive sands at greater depth, and the possibilities of the Whiteface dome should not be considered exhausted until deep drilling has established the presence or absence of these lower beds.

Good locations for testing this dome are the southwest corner of the SE. ¼ and the center of the SW. ¼ sec. 35, T. 27 N., R. 7 E., and the southeast corner of the NW. ¼ sec. 2, T. 26 N., R. 7 E. A well drilled at any of these locations should not be abandoned until a depth of at least 2,700 feet is attained, unless oil or gas is encountered at less depth.

TPS. 24, 25, AND 26 N., RS. 6 AND 7 E.; TPS. 25 AND 26 N., R. 5 E.; T. 26 N., R. 4 E.

By C. F. Bowen.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL FEATURES.

The rocks exposed in Tps. 24, 25, and 26 N., Rs. 6 and 7 E.; Tps. 25 and 26 N., R. 5 E.; and T. 26 N., R. 4 E. (see fig. 1), are illustrated graphically in the columnar section on Plate XXII. They have an aggregate thickness of about 1,100 feet and are of upper Pennsylvanian and lower Permian age. They consist of numerous beds of limestone, ranging in thickness from a few inches to 15 feet or more, interstratified with beds of sandstone and shale. The sandstones are thicker and more numerous in the upper and lower portions of the section than in the middle, and many of them are lenticular, wedging out toward the north. Above the Neva limestone all the rocks except the limestones are red; below the Neva more somber colors predominate, though some of the shales have reddish hues. The limestones are of the greatest aid in working out the structure of the region, hence the most prominent and characteristic of them will be described, but no detailed description of the stratigraphy as a whole will be given.

KEY BEDS.

Bird Creek limestone.—The Bird Creek limestone is the lowest one exposed over any considerable part of the area. It is a dense, fine-grained noncrystalline rock about 4 feet thick. On the fresh surface it is commonly lead-gray to black and weathers to a dirty buff or yellow. When struck with the hammer it breaks along bedding planes with comparatively smooth surfaces. It contains fossils of a few species but they are not abundant. It is hard and seems fairly resistant to erosion but does not produce a marked topographic effect in this area. It was named by Heald[1] from exposures on Bird Creek, in T. 27 N., R. 8 E.

Cryptozoon-bearing limestone.—The *Cryptozoon*-bearing limestone is about 80 feet above the Bird Creek limestone. It is a compact noncrystalline black limestone, overlain in the southern part of the area by a bed which weathers yellow. It is distinguished from the Bird Creek limestone and others which it resembles lithologically by the presence of fossil Cryptozoa and *Fusulina*. In places the Cryptozoa are rather scarce, but they can generally be found by making a careful search, especially if the outcrop of the bed is followed for some distance. As a rule the outcrop of the bed does not produce conspicuous topographic features, and in many places it is concealed by wash, but it is an extremely valuable key bed because of the certainty with which it can generally be recognized.

Stonebreaker limestone.—The Stonebreaker consists of three or more beds of limestone separated by shale and sandstone, the whole having a thickness of 30 to 40 feet. The middle bed of limestone is the most distinctive bed of the division. It is a finely crystalline gray to brownish ferruginous limestone which weathers to a brownish color. In the northern part of the area the upper part of this bed is marked by a layer or discontinuous masses of rock which weathers to a deep limonitic brown and contains Cryptozoa, a few *Fusulina*, and fragments of other fossils. In the southern part of the area the limonitic color is not so constant and may appear at other horizons than the top of the bed; the Cryptozoa decrease in number and prominence and the *Fusulina* greatly increase, so that they become the most characteristic fossils.

The upper bed of limestone is a gray to drab crystalline rock, 4 or 5 feet thick, containing an abundance of comminuted fossil remains and in the southern part of the area some small *Fusulina*. It is distinguished from the middle bed by the absence of Cryptozoa, the smaller size of the contained *Fusulina*, and the general absence of limonitic color, through locally it is strongly limonitized. The sandstones above the Stonebreaker as a rule form rather prominent ridges or scarps, which constitute a valuable guide in following the limestones.

Grayhorse limestone.—The Grayhorse limestone is named from its excellent exposure on the crest of the Little Grayhorse anticline, in the NW. ¼ sec. 11, T. 24 N., R. 6 E. It is also well exhibited in the high point in the NE. ¼ sec. 33, T. 26 N., R. 7 E., in the upper part of the drainage basin of Clear Creek, and is one of the most distinctive key rocks in the area herein described. It is a dark brownish-gray crystalline conglomeratic limestone, commonly about 2 feet

[1] Heald, K. C., report on T. 27 N., R. 8 E., in preparation to form a part of Bulletin 686.

thick but locally as much as 4 feet thick. It contains numerous small pebbles ranging in size from mere grains to pebbles as large as a large pea, which weather to a dirty-white color and give the weathered surface of the rock a mottled appearance. In most places it also contains numerous large fossils of the species *Myalina subquadrata*, some of which are 3 or 4 inches in their longest dimension. Where it crops out on steep slopes the bed breaks off in large slabs, as much as 10 feet across, which strew the slope below. The bed is so distinctive that after having once been identified it is generally recognized without difficulty, and it is therefore a valuable key bed.

Foraker limestone.—The Foraker limestone comprises several beds of limestone interstratified with shale and some sandstone, having an aggregate thickness of about 100 feet. The limestones are characterized by an abundance of *Fusulina* throughout and few other distinguishable fossils. For convenience of description the formation may be separated into three divisions.

The lower division consists of two thin limestones overlain by 45 feet of shale and sandstone, the beds of which increase in number and thickness toward the south. Because of their thinness and lithologic uniformity the limestones at the base of this division constitute valuable key beds. The lower bed is about 2 feet thick, has a gray color when fresh, weathers to yellow or light brown, and in addition to *Fusulina* contains locally brachiopods, *Myalina*, and other fossils. The upper of these two beds is separated from the lower by 5 to 8 feet of shale. The limestone is about 1 foot thick, is dense and fine grained, has a dark-gray to black color, and contains small *Fusulina*. These beds are resistant to erosion and are commonly well exposed, notwithstanding the fact that they crop out at the base of a steep slope.

The middle division of the Foraker consists of a limestone about 2 to 5 feet thick overlain by 15 feet of shale. The lower part of the limestone is dense, fine grained, and black and contains medium-sized *Fusulina* which exhibit a pale flesh color on a freshly broken surface. Overlying this is a somewhat limonitic bed that weathers yellow or light brown. In the southern part of the area this limestone is directly overlain by a sandstone which thins toward the north and west and is absent or very thin in T. 26 N.

The upper division consists of three or more limestones separated by thin beds of shale. The limestones are gray to white, and those at the top weather light yellow in the southern part of the area. They are all thickly crowded with large *Fusulina*. In T. 26 N. one of the limestone beds about the middle of this upper division contains a large amount of chert nodules which on the fresh surface exhibit a pale blue color and are inset with numerous large white *Fusulina*. This chert is almost entirely absent south of the boundary between

Tps. 25 and 26 N. The limestones of this upper division produce a broad sloping surface which terminates on the east in a sharp rim or scarp.

Red Eagle limestone.—The Red Eagle limestone is a gray crystalline limestone ranging from 12 to 25 feet in thickness. In some places parts of the bed are slightly limonitic and weather yellow. Where thickest the Red Eagle consists of several beds of limestone separated by beds of shale. In other places the shale seems to be absent. In such places only the upper part of the bed is commonly exposed, but its entire thickness seems to be about 10 or 12 feet. The limestone contains few if any fossils and because of its changeable thickness is not a good key bed.

Neva limestone.—The Neva limestone as here identified comprises four thin beds of limestone separated by beds of gray shale. A compiled section measured in the vicinity of Burbank is as follows:

Section of Neva limestone near Burbank.

	Feet.
Limestone, gray, somewhat cherty, soluble; chert commonly lying loose on the surface	2
Shale	6±
Limestone, gray, containing large nodules of chert; both chert and limestone full of large *Fusulina*. Chert nodules white on freshly broken surface; weather brown with a sandy appearance. These nodules strew the surface so thickly that wheeling over them is difficult	2
Shale	8
Limestone, gray; weathers white; contains no fossils or chert; weathers into large, thin, sharp-edged slabs; forms prominent rim	4
Shale	12
Limestone, dense, noncrystalline; has straw-yellow color streaked with maroon; contains pelecypods; rarely well exposed	2½
	36½

Cottonwood limestone.—The Cottonwood lies about 80 feet above the Neva and is a light-gray to white crystalline limestone. The lower part is slightly conglomeratic or oolitic in some places, but this feature does not seem to be constant. In some places *Fusulina* occur in the upper part of the bed and gastropods and other fossils in the lower part. The bed is 4½ feet thick in a cut on the Atchison, Topeka & Santa Fe Railway in sec. 9, T. 26 N., R. 5 E.

Crouse limestone.—The Crouse limestone is about 130 feet above the Cottonwood. In its most common aspect it is a light-gray thin-bedded, ledge-making limestone, 6 to 13 feet thick. Large massive buff blocks as much as 12 or 15 feet in length and comprising the entire thickness of the bed replace the bedded mass at short intervals along the outcrop. The limestone is very porous, both in vertical faces and in its flat upper surface, where large cylindrical holes, vertical or nearly so, are very numerous. In some places a bed near the top is literally filled with small Foraminifera. Here and there also the lower 2 or 3 feet of the bed is finely and abundantly conglomeratic, but this feature is not common.

Wreford limestone.—The term Wreford is here applied to two limestones separated by about 20 feet of sandstone and shale, lying about 92 feet above the Crouse. The upper limestone may belong to the Fort Riley, but not enough work has yet been done by the writer to determine this point. The lower limestone is a bedded limestone about 8 or 10 feet thick, of which only the upper 4 or 5 feet is commonly exposed. At the base it is light brown; above the basal part it is gray with a slight buff tinge, weathers into large slabs, and forms broad sloping terraces that terminate along drainage lines or along its eastern front in a high ledge or scarp. The upper limestone consists of a lower yellow fossiliferous bed about 2 feet thick, overlain by a bed of cellular light-gray crystalline rock. One peculiar feature in this area is that no chert was seen associated with either of the limestone beds referred to the Wreford, although chert is characteristic of it in all other localities where it has been studied.

UNEXPOSED ROCKS.

STRATIGRAPHIC RELATIONS.

The rocks not exposed at the surface which have been penetrated by the drill in or adjacent to the western part of the Osage Reservation are shown in Plate XXI. Of the five well records shown, only one of them represents a well drilled within the area under consideration. The relation of the productive sands and of the "Oswego lime" and "Mississippi lime" to the key beds of the exposed rocks, as indicated by a comparison of the well logs and the columnar section of exposed rocks, is shown in tabular form below. The figures given are of course only approximations, based on the assumption that the intervals between the beds remain constant.

Intervals, estimated to nearest 50 feet, between key beds at surface and important beds not exposed.

Key bed.	Layton sand.	Cleveland sand.	"Oswego lime."	"Mississippi lime."
Base of Wreford limestone	2,500	2,650–2,800	3,000	3,600
Crouse limestone	2,400	2,550–2,700	2,900	3,500
Cottonwood limestone	2,250	2,400–2,550	2,750	3,350
Base of Neva limestone	2,150	2,300–2,450	2,650	3,250
Red Eagle limestone	2,100	2,350–2,400	2,600	3,200
Base of Foraker limestone	1,950	2,100–2,250	2,450	3,050
Grayhorse limestone	1,850	2,000–2,150	2,350	2,950
Top of Stonebreaker limestone	1,700	1,850–2,000	2,200	2,800
Cryptozoon-bearing limestone	1,600	1,750–1,900	2,100	2,700
Bird Creek limestone	1,500	1,650–1,800	2,000	2,600

This table gives an idea of the depth at which the productive sands of the Cleveland pool, to the southeast, and of deeper sands in other productive fields in Oklahoma should be reached in any particular part of the area discussed. This statement assumes, of course, that these sands extend across the "western Osage," an assumption which has not been verified but which seems to be borne out by the well records in adjacent territory on the east, south, and west.

OIL AND GAS BEARING BEDS.

In the Cleveland pool, in T. 21 N., R. 8 E., oil is found in the Layton, Cleveland, Bartlesville, and Tucker sands. The Bartlesville lies at a depth of 575 to 675 feet below the Cleveland, and the Tucker at 200 to 300 feet below the Bartlesville. In the Pawhuska quadrangle, in the eastern part of Osage County, oil and gas are obtained at two or more horizons in the "Mississippi lime," also in the Bartlesville (here including the Tucker sand), the "Oswego lime," sands between the "Oswego" and Big limes, the Big lime, and a sand about 100 feet above the Big lime. It is reasonably certain that some of these sands underlie the "western Osage," and the inference is warranted that oil and gas will be found in them where structural and other conditions favor accumulation. The Ponca City field obtains its oil and gas from shallow sands, most of which are exposed in the "western Osage." The probable relation of these sands to the key beds described in this report is shown in columns 6 and 7 of Plate XXI. It is probable that some of these shallow sands also contain oil and gas in the western part of the Osage Reservation in areas sufficiently removed from the outcrop of the sands.

STRUCTURE.

GENERAL FEATURES.

The rocks in the area described show an average westward dip of about 35 feet to the mile, or a little less than half a degree. The westward dip is more constant here than in the eastern part of the Osage Reservation, and there are fewer deviations from the general regional structure and consequently fewer anticlines and domes.

Because of this regional westward dip, the rocks that form the surface are successively younger and higher stratigraphically toward the west. For this reason the rocks that appear at the surface in the "western Osage" have been eroded from most of the Pawhuska quadrangle and areas farther east, and conversely the surface rocks in those areas lie below the surface of the "western Osage" and are not open to inspection. The convergences which are known to occur between these lower rocks in the Pawhuska quadrangle therefore can not be taken into account in the western region, and the

higher the position of the surface beds in the geologic column the more widely may they depart from parallelism with the rocks below, especially those which, like the "Oswego lime" and "Mississippi lime," lie at depths ranging between 2,000 and 3,600 feet. This feature precludes the possibility of matching structure contours that are drawn on widely separated reference horizons. Some discrepancy appears in the contours drawn along the common margin between the area herein described and the Pawhuska quadrangle or "eastern Osage." This same lack of parallelism between beds also makes difficult the correlation of beds encountered in drilling over wide areas. The correlations shown on Plate XXI are therefore suggestive and tentative rather than conclusive, but they are based on a careful study of the columnar sections of rocks exposed in both the western and eastern Osage and a comparison of these sections with the logs of wells whose approximate surface horizons are known.

The correlation of the Ponca City sands with the stratigraphic section of the western part of the Osage Reservation, as shown in Plate XXI, is slightly different from that suggested by Ohern and Garrett.[1] The correlation here given indicates that the 500-foot sand of the Ponca City field is probably equivalent to one of the sands associated with the Cottonwood limestone; that the "fourth sand" is probably equivalent to the sandstone above the Stonebreaker limestone which crops out about 4 to 6 miles west of Fairfax; and that the lowest productive sand is at approximately the same position as the Elgin sandstone. On this basis the deep sand in the well on the 101 ranch, in the Ponca City field, is probably the equivalent of the Layton instead of the Cleveland sand of the Cleveland field.

The structure contours shown on Plates XXII and XXIII are drawn on the Bird Creek limestone. In the following pages anticlines and domes are described by ranges from east to west.

ANTICLINES AND DOMES.

R. 7 E.

Little Chief terrace.—The Little Chief terrace occupies most of sec. 16, T. 26 N., R. 7 E. Its upper surface is about three-quarters of a mile wide and slopes very gently to the west. East of the flat or terrace the westward dip amounts to about 40 feet in the first mile and a half; on the west the rocks dip about 35 feet in the first half mile. The base of the Foraker limestone crops out in a north-south direction across the surface of the terrace, and along this line of outcrop the depths to the "Oswego lime" and the "Mississippi lime" are estimated to be 2,450 feet and 2,950 to 3,050 feet, respectively. Terraces of this character are commonly considered less favorable

[1] Ohern, D. W., and Garrett, R. E., The Ponca City oil and gas field: Oklahoma Geol. Survey Bull. 16, p. 27, 1912.

for the accumulation of oil and gas than anticlines or domes and are therefore not recommended as places for initial tests in unexplored territory. A large, well-defined terrace may, however, furnish as favorable conditions as an anticlinal "nose" that has no eastward dip or reversal. If the domes near by are found to contain oil and gas, this terrace would offer the next best chance in the immediate vicinity. Probably the best place for a test well on this terrace is part way down the west slope, and therefore the center of the NW. ¼ sec. 16 and a point about 1,500 feet north and 500 feet east from the southwest corner of the section are recommended as favorable places for testing the terrace in the event that oil or gas are found in the more favorable domes near by.

Upper Little Chief dome.—The Upper Little Chief dome occupies parts of secs. 19, 20, 29, and 30, T. 26 N., and covers an area of nearly 2 square miles. It has an east closure of 20 feet over an area of nearly half a square mile. The crest of the dome lies a few hundred feet about due south of the north quarter corner of sec. 29. The dips in all directions are relatively gentle. The surface rock is a thin limestone about 30 feet below the base of the Foraker limestone. The "Oswego lime" is therefore estimated to lie at a depth of about 2,400 feet and the "Mississippi lime" at about 3,000 feet. The outline of the dome is based on elevations on the Foraker limestone and the thin beds below it. There is an extensive gathering ground on the west of the fold.

Lower Little Chief dome.—The Lower Little Chief dome lies mainly in sec. 31, T. 26 N., and sec. 6, T. 25 N., but extends westward into the adjoining sections in R. 6 E. The outline of the dome is based on elevations on the Grayhorse and Foraker limestones and the thin limestones which lie between them. Its crest lies about 1,500 feet east-northeast of the southwest corner of sec. 31, T. 26 N., and it has a closure of about 10 feet. The dip to the north and south is gentle, but that on the west amounts to about 100 feet in the first mile. This dome is small but has an extensive gathering ground. The "Oswego lime" is estimated to lie at a depth of about 2,350 feet below its crest, and the "Mississippi lime" at about 2,800 to 2,950 feet.

Clear Creek anticline.—The Clear Creek anticline extends northwestward through secs. 13, 12, 11, and 10, T. 25 N. It is a low nose with gentle north and south dips but no eastward reversal. Its contouring is based on elevations taken on the *Cryptozoon*-bearing limestone and the several beds of the Stonebreaker limestone. It has an ample gathering ground to the west, north, and south, but its structural value as a possible oil and gas reservoir is questionable. Drilling is not recommended on folds of this type until it is demonstrated that oil or gas occurs in the larger, better-defined domes of the area. The best place for drilling would be along the crest of the fold, probably well toward its east end or near the northwest corner of sec. 13.

Upper Grayhorse anticline.—The Upper Grayhorse anticline lies chiefly in sec. 31, T. 25 N. Its outline as shown is based principally on elevations on a thin limestone lying about 20 to 25 feet below the Grayhorse limestone. It covers an area of about half a square mile and has well-defined dips to the north, south, and west. There is no east dip. The crest of the anticline probably lies about 1,200 feet northwest of the southeast corner of sec. 31, and the depth at that point to the "Oswego lime" and "Mississippi lime" is estimated to be about 2,300 and 2,900 feet, respectively.

North Hominy Creek anticline.—The North Hominy Creek anticline is the most pronounced fold in the area covered by this report. It occupies all of sec. 22 and parts of the surrounding sections in T. 24 N. Its contouring is based on elevations on the Bird Creek, *Cryptozoon*-bearing, and Stonebreaker limestones and other thin limestones lying between these key beds. The fold has an east closure of 10 to 15 feet. The dips to the north and south amount to about 30 feet in the first half mile, and that to the west is about 100 feet in the first mile. The fold has a large gathering ground from which oil and gas may have been obtained, and because of its nearness to productive oil and gas territory on the east it is considered the most favorable structure of the area here discussed. The highest point on the anticline is in the SW. ¼ NE. ¼ sec. 22, and at that place the "Oswego lime" is estimated to be at a depth of about 2,000 feet and the "Mississippi lime" at 2,500 to 2,600 feet below the surface.

South Hominy Creek anticline.—The South Hominy Creek anticline occupies secs. 25 and 36, T. 24 N., but the greater part of it extends eastward into the Pawhuska quadrangle. That part of the fold lying in the "western Osage" was outlined by elevations on the Bird Creek limestone, which shows north, south, and west dips. The anticline has a fairly good gathering ground and is regarded as affording good opportunity for the accumulation of oil and gas. The highest part of the fold and therefore the best place for a test well is probably about the center of the SE. ¼ sec. 25.

R. 6 E.

Upper Salt Creek dome.—The Upper Salt Creek dome occupies parts of secs. 3, 4, 5, 8, 9, and 10, T. 26 N., the northern part of it extending into the Foraker quadrangle. The outline of the fold as shown on the map is based chiefly on elevations on the Red Eagle limestone and beds in the upper part of the Foraker. It probably has a closure on the northeast of 10 to 20 feet. An east dip of 15 feet in about half a mile is shown in the SE. ¼ sec. 9; on the west the dip amounts to 90 feet in the first mile. The dome has an extensive gathering ground, and structurally offers good possibilities for the accumulation of oil and gas. Its crest lies a little northwest of the center of sec. 9, and at that point the "Oswego lime" should be reached at about 2,600 feet and the "Mississippi lime" at 3,100 to 3,200 feet.

North Lostman anticline.—The North Lostman anticline is a southwestward-trending nose with a slight dip to the north and south but no dip to the east, extending diagonally across sec. 33 and into the southwest corner of sec. 32, T. 26 N. It is not recommended for drilling until other more favorable folds have been tested.

South Lostman anticline.—The South Lostman anticline occupies parts of secs. 3, 4, 5, 8, and 9, T. 25 N., and covers about 1½ square miles. Its outline was determined by elevations taken on beds of the Foraker limestone. Its crest has a low saddle about the middle. The anticline has an east closure of about 10 feet; the dip to the north and south is gentle; that to the west amounts to about 70 feet in the first mile. The highest points on the anticline lie about 1,200 feet northeast of the west quarter corner of sec. 3, and 1,500 feet northeast of the southeast corner of sec. 4. At these places the "Oswego lime" is estimated to be about 2,550 feet below the surface and the "Mississippi lime" 500 to 600 feet lower.

Solomon Creek anticline.—The Solomon Creek anticline is a very small fold in the N. ½ sec. 21, T. 25 N., covering less than a quarter of a square mile. The east dip is less than 10 feet, as determined by observations on beds of the Foraker limestone. The fold is too small to be of much importance and should not be drilled until the larger folds have been tested.

Deadman anticline.—The Deadman anticline is another small fold, about comparable in size to the Solomon Creek anticline, lying in the S. ½ sec. 33, T. 25 N. Elevations taken on beds in the Foraker limestone show that the east dip is about 8 feet and the north and south dips are very small. The fold is not recommended as favorable for a test well in this part of the "western Osage" before more promising fields are drilled.

Little Grayhorse anticline.—The Little Grayhorse anticline is a long, narrow fold extending from the NW. ¼ sec. 1 to the south side of sec. 10, T. 24 N. Its outline, determined from elevations taken on the Grayhorse limestone and the thin limestones below it, shows that it has gentle north, south, and west dips but no eastward dip except a very slight sag crossing the main axis at right angles in the north-central part of sec. 11. The fold has a good gathering ground on the north and west. From its highest point in the NW. ¼ sec. 11 the "Oswego lime" and "Mississippi lime" are estimated to lie at depth of 2,350 and 2,950 feet, respectively.

Middle Grayhorse anticline.—The Middle Grayhorse anticline lies mainly in sec. 25, T. 24 N., but extends eastward into sec. 30, T. 24, N., R. 7 E. This fold, whose outline was determined by elevations on beds of the Stonebreaker limestone and the thin limestone above it, is in reality a broad, flat terrace with slight dips to the north and south and somewhat steeper dips on the west. Its upper surface is nearly level in an east-west direction. It is not recommended for drilling until other more favorable folds have been tested.

Lower Grayhorse anticline.—The Lower Grayhorse anticline is a very low, narrow fold about 1½ miles long lying mainly in secs. 35 and 36, T. 24 N. Its outline as mapped is based on elevations on the top of the Stonebreaker limestone and a thin limestone about 20 to 25 feet above it. There is a slight east dip at the extreme east end of the fold, in sec. 31, T. 24 N., R. 7 E. West of this point the axis has a very slight dip to the west for a mile and a half and steepens to about 40 feet in the next half mile. The dips to the north and south are not more than 15 feet. The fold is not of sufficient promise to warrant drilling until more favorable folds have been thoroughly tested. The most favorable localities for test wells are 1,000 feet south and 300 feet west from the northeast corner of sec. 36 and near the west quarter corner of the same section.

Lower Salt Creek anticline.—The Lower Salt Creek anticline is a low, narrow fold trending northwest across sec. 30, T. 24 N. Elevations on the Grayhorse limestone and the thin limestones above it disclose a southeast dip of about 10 feet extending for nearly half a mile southeastward from the center of sec. 30. The dips to the northeast, southwest, and west are low.

R. 5 E.

East Bluff Creek anticline.—The East Bluff Creek anticline is a broad, gentle fold lying mainly in the SW. ¼ sec. 17 and the SE. ¼ sec. 18, T. 26 N. Its outline was determined by elevations on the Crouse limestone which indicate an east dip of about 8 feet extending eastward for about a quarter of a mile from the center of the small area inclosed by the 280-foot contour. The dip to the north and south is gentle and amounts to not more than 20 feet. The anticline is therefore little more than a broad wrinkle, of insufficient promise to warrant drilling unless more pronounced folds are found to contain oil and gas.

Jim Creek anticline.—The Jim Creek anticline is a low, broad nose, very similar in form to the East Bluff Creek anticline, in secs. 31 and 32, T. 26 N. Its shape was determined by elevations taken on the Crouse limestone. The dip to the north and south amounts to about 20 feet in half a mile; it has no eastward dip.

R. 4 E.

West Bluff Creek dome.—The West Bluff Creek dome is a very gentle oblong upwarp whose outline was determined from elevations on the Crouse and Wreford limestones. It lies in secs. 13 and 24, T. 26 N., covers an area of nearly 1 square mile, and has a closure of one contour over about half that area. The eastward dip amounts to only about 8 feet, and the dips to the north, south, and west are gentle. The dome has a sufficiently large gathering ground on the west and southwest to afford an accumulation of oil or gas. The crest of the dome lies a few hundred feet northwest of the south quarter corner of sec. 13. The depth to the "Oswego lime" and "Mississippi lime" at this point is about 2,900 and 3,500 feet, respectively.

Schoolhouse anticline.—The Schoolhouse anticline is a westward-plunging nose, terminating on the east in a terrace and occupying most of sec. 27 and part of the north side of sec. 28 and the south side of sec. 21. The outline of the fold was determined by elevations on the Wreford limestone. The dip to the north is about 20 feet in the first half mile; that to the southwest averages 50 feet, and that to the west about 90 feet to the mile. The "Oswego lime" is estimated to lie at a depth of about 3,000 feet and the "Mississippi lime" at about 3,600 feet below the crest of the fold in the center of the NE. ¼ sec. 27, which would be the best locality for a test well. So far as structural conditions are concerned the fold affords good possibilities for the accumulation of oil and gas.

TPS. 24 AND 25 N., R. 8 E.

By K. C. HEALD and KIRTLEY F. MATHER.

INTRODUCTION.

The greater part of the field work in Tps. 24 and 25 N., R. 8 E. (see fig. 1), was done by K. C. Heald and K. F. Mather, assisted respectively by J. Lee Bossemeyer and M. G. Gulley, instrument men. Mr. Heald is in the main responsible for the work in the western half of T. 25 N., R. 8 E., and Mr. Mather for that in the eastern half. The areas mapped by the two geologists in T. 24 N., R. 8 E., interfinger intricately so that it is not practicable to indicate the portion worked by each man. Certain small areas in the southeast corner of this township were mapped by F. R. Clark assisted by P. V. Roundy, and in some other parts of the township J. T. Richards served as instrument man.

STRATIGRAPHY.

EXPOSED ROCKS.

The exposed rocks in these townships are all of Upper Pennsylvanian age and include sandstone, limestone, and shale with an aggregate thickness of about 500 feet. Sandstones and shales predominate, but limestone beds recur in a number of different zones between the top and bottom of the section. Certain of these beds crop out conspicuously in many different parts of the two townships. Generalized geologic sections indicating the nature of the exposed rocks and the intervals between the successive beds of sandstone and limestone are presented in figure 26. The vertical intervals vary materially from place to place, but those recorded in the sections are approximate averages for the region under discussion. In general, there is a marked convergence of the limestones above the Deer Creek limestone toward the south and, on the contrary, a marked divergence between the Lecompton and Deer Creek limestones in the same direction.

The geologic structure was determined from elevations taken on a great number of beds. Some of these beds have only a very local development, but others may be traced for long distances. The more persistent and helpful of these key beds are described briefly below.

Okay limestone.—The Okay limestone is a thin bed, commonly inconspicuous, occurring in the lower part of the Pawhuska limestone, about 10 feet above the highest bed of the Elgin sandstone and 50

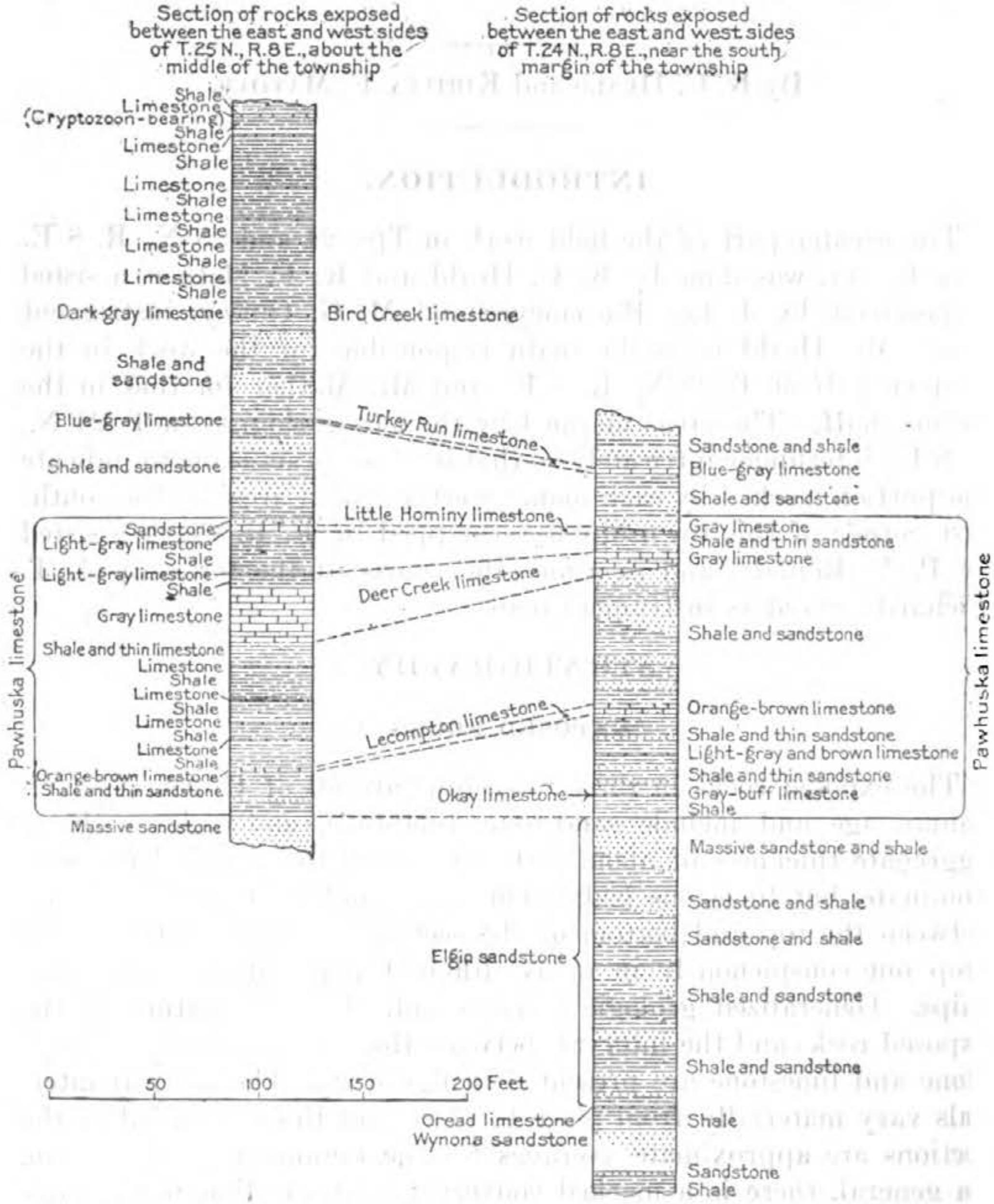


FIGURE 26.—Stratigraphic section showing rocks exposed in Tps. 24 and 25 N., R. 8 E.

to 100 feet below the Deer Creek limestone member of the Pawhuska. It was named[1] from its good exposures on and in the neighborhood of the O. K. ranch in sec. 31, T. 25 N., R. 9 E. It is probably a rather small lentil of only local importance, cropping out sporadically in different parts of T. 24 N., R. 8 E., and the neighboring townships

[1] Heald, K. C., report on T. 25 N., R. 9 E.: U. S. Geol. Survey Bull. 686–E, 1918.

toward the east and northeast. Where present it may be found easily because of its stratigraphic position with respect to the underlying massive Elgin sandstone.

The color of this limestone varies from gray to buff, with buff predominating. In most places it is characterized by a flinty hardness and an abundance of small *Fusulina*, but locally either or both of these features may be absent. Typical exposures may be observed in secs. 12 and 13, T. 24 N., R. 8 E.

Lecompton limestone.—The Lecompton limestone is a member of the Pawhuska formation, lying 30 to 60 feet below the Deer Creek limestone, which is the "Pawhuska lime" of commercial geologists. This bed is one of the most persistent of the members of the Pawhuska limestone and has been traced from the Kansas line through the Pawhuska quadrangle, through the Hominy quadrangle, where it is known to some as the "Hominy lime," and southward to the Cushing field, where it is known as the "Pawhuska lime."

It is a hard bed, which ranges from 2 to 5 feet in thickness in these townships but which is much thicker in the region to the south. In many places it forms a conspicuous outcrop and large slabs break from the ledge and litter the hill slopes. Its resistance to disintegration may lead to errors, as some of these slabs, which show little or no effect of weathering, occur on slopes or in stream beds far below the actual outcrop of the limestone.

The weathered color is commonly an orange or orange-brown, though locally it is gray. The fresh surface is lighter in color. The limestone is not markedly fossiliferous except in small areas, but almost everywhere a search will reveal small cup corals (*Lophophyllum profundum*).

The outcrops that may be seen near the east-west road in secs. 1, 2, and 3, T. 24 N., R. 8 E., are typical.

Deer Creek limestone.—The Deer Creek limestone is the most conspicuous member of the Pawhuska formation. It is about 26 feet thick in T. 25 N., R. 8 E., but becomes much thinner toward the south, where its lower beds are replaced by sandstone. The general color of the weathered surface is gray, but it shows some bands which are cinnamon-brown and blackish blue and, fortunately, are so persistent that they can be traced for considerable distances and used in mapping to determine structure. Resistance to erosion varies materially both horizontally and vertically within the member, so that the "ledge maker" is a different bed at different localities.

Throughout the greater part of T. 25 N., R. 8 E., a brown band, 3 or 4 feet thick, near the top of the Deer Creek limestone, proved especially helpful in the detailed mapping. At many places also the very top of the member, which is dark blackish blue and has a peculiar velvety-smooth appearance, was used. Elsewhere a thin bed of gray limestone about 7 feet above the massive ledge proved the most reliable stratum.

As this limestone is traced southward into T. 24 N., R. 8 E., the brown band becomes extremely irregular, the black bed disappears, the interval immediately below the thin upper bed becomes more and more calcareous, and the lower beds change somewhat abruptly into sandstone diagonally across the member from the base upward. South of Little Hominy Creek, therefore, the outcrop of the Deer Creek limestone indicated on the map (Pl. XXIV) is that of a bed at a horizon 7 feet higher than that represented farther north.

Little Hominy limestone.—The Little Hominy limestone is a bed 3 to 15 feet thick lying between 12 and 30 feet above the Deer Creek member of the Pawhuska limestone. It is persistent and conspicuous in T. 27 N., R. 8 E., where it maintains a constant position 30 feet above the Deer Creek limestone, but its outcrop is found to become intermittent and variable when traced southward into T. 25 N., R. 8 E.; about midway of that township it begins to converge toward the lower limestone, and in the southwest quarter of T. 24 N., R. 8 E., where its rare outcrops are last observed, the two limestone beds are only 12 feet apart.

Typically the Little Hominy limestone is light gray on the weathered surface, somewhat darker where freshly broken, and very coarsely crystalline. In many places the uppermost 3 to 6 inches of this member consists of very impure conglomeratic limestone containing many shell fragments. At certain localities well-preserved *Fusulina*, brachiopods, gastropods, and other organisms are present, but at most places good fossils are lacking.

In the southern half of T. 25 N., R. 8 E., and wherever observed in T. 24 N., R. 8 E., this limestone is unusually sandy, containing from 20 to 30 per cent of clear, glistening quartz grains. In places this proportion is greatly exceeded, and it is impossible to separate the limestone from the overlying massive sandstone, a bed which, in the absence of the Little Hominy limestone, has proved very serviceable in detailed mapping. It is probable that the abrupt disappearance of this limestone at many localities is due to its transition from a sandy lime into a calcareous sandstone that is indistinguishable from the overlying sands.

Good exposures may be observed on the west slope of the southward-trending valley in the SW. ¼ sec. 30, T. 25 N., R. 8 E., and south of Hominy Creek in the SE. ¼ sec. 30, T. 24 N., R. 8 E. The bed is named from its outcrops on Little Hominy Creek in the southwestern part of T. 25 N., R. 8 E. This member is probably the equivalent of either the Howard or the Topeka limestone of Kansas.

Turkey Run limestone.—From 40 to 90 feet above the Deer Creek member of the Pawhuska limestone is a dark-gray limestone, 1 to 3 feet thick, to which the name Turkey Run limestone is here applied because of its excellent exposures near the head of Turkey Run, in secs. 9, 16, and 17, T. 24 N., R. 8 E. As in the case of the Little Hominy limestone the interval between this bed and the underlying limestone is greatest in the northern part of T. 25 N., R. 8 E., and least near the south margin of T. 24 N., R. 8 E.

This limestone is fine grained, thin bedded, hard, and brittle and weathers into smoothly rounded slabs a few inches in length. The weathered surface is generally light gray with many curving traceries and irregular patterns of darker gray or yellowish brown, due to the fragments of brachiopod and gastropod shells, the margins of which are thus etched by weathering. On fresh fracture the color is a much darker bluish gray, at some localities almost black. Well-preserved fosils are extremely rare; in fact, it may most readily be distinguished from the lithologically similar limestone 60 feet higher in the section by the absence of the brachiopod species commonly found in the higher bed.

Bird Creek limestone.—The next limestone above the Turkey Run bed, just referred to, has been named the Bird Creek limestone, for there are many good outcrops along the headwaters and main branches of Bird Creek in the townships immediately north of those now under consideration. The exposures along the south side of South Bird Creek in secs. 28 and 29, T. 26 N., R. 8 E., are typical of its development there. In the SE. ¼ sec. 4, T. 25 N., R. 8 E., it is crossed by the Fairfax road, and in T. 24 N., R. 8 E., it may be seen to good advantage along the northwest-southeast road in sec. 8.

Near the north margin of T. 25 N., R. 8 E., the Bird Creek limestone is 50 feet above the Turkey Run limestone; 6 miles farther south the interval has increased to 72 feet. The two beds are very similar in general appearance, but the upper one is slightly darker than the lower and contains fewer fossil fragments. On the other hand, the Bird Creek limestone carries many more complete fossil shells and is indeed characterized by the presence of the brachiopod *Enteletes hemiplicata* at nearly every outcrop. Another method of distinguishing between the two beds depends upon the presence of a thin soft limestone, crowded with *Fusulina*, about 18 or 20 feet above the Bird Creek limestone.

UNEXPOSED ROCKS.

The unexposed rocks of Pennsylvanian age are of the same general type as those that appear at the surface. Sandstone and shale form about 90 per cent of the total above what is known to the drillers as the Big lime (probably the Pawnee limestone of the Kansas section). Below that horizon there is comparatively little sandstone, but there are massive beds of limestone and thick series of shale. (See Pl. XXVI.)

Many of the sandstones in the upper part of the section contain water, even in areas of pronounced anticlinal structure, and in some of the synclines they yield enormous quantities of either salt or fresh water. Most of these water-bearing sands seem to be lenticular, for not all the wells, even those that are closely spaced, get the water at the same horizon. One of these sands, which in most localities appears to be heavily charged with salt water, is very persistent and will probably be encountered in many of the wells drilled in these townships. Its top is between 480 and 560 feet below the horizon of the Lecompton limestone.

Either oil or gas has been found in more than a dozen distinct beds in the different wells which have been drilled in these townships. Most of these beds contained only "showings" which were not large enough to be commercially important, although they indicate the possibility of obtaining oil from the beds in which they were found, but at least four zones have been proved to contain sufficient oil or gas to justify the expense of drilling and equipping wells. The uppermost of these zones is about 1,200 feet below the Lecompton limestone; in the oil field in the southeast corner of T. 24 N., R. 8 E., where it is known as the Layton sand, it has thus far been reported to yield only small volumes of gas and oil. The Big lime lies 500 or 600 feet lower, and in two or three of the wells in the field mentioned above it has contributed a little gas and oil to the total production. More important is a sand about 25 feet thick known as the Peru sand which lies immediately below the Big lime; this is the "little pay" in a few of the oil wells. The Fort Scott limestone ("Oswego lime") is about 2,000 feet below the Lecompton limestone and in some places is immediately overlain by a thin oil-bearing bed known as the Wheeler sand. This zone is penetrated at a depth of about 1,750 feet in the wells in the southeast corner of T. 24 N., R. 8 E., and from it the majority of the wells in that field get their oil. About 300 feet below these beds is a sand about 15 feet thick which lies immediately on or a very short distance above the "Mississippi lime" and yields both oil and gas in favored localities. This sand is known as the Bartlesville sand in the oil field mentioned above and has yielded good returns in several of the wells there.

Besides the oil and gas bearing formations mentioned above, there are unquestionably deeper sands 200 feet or more below any which have been reached by drilling operations in these two townships.

The highest of these deep-lying sands has been proved to contain both oil and gas in other parts of the Osage Reservation, and it seems practically certain that future deep drilling in these townships will result in obtaining a good yield from one or more of these lower beds.

GEOLOGIC STRUCTURE.

GENERAL STRUCTURE.

The structure in Tps. 24 and 25 N., R. 8 E. (see Pls. XXIV, XXV), is complicated. In general there is a regional downward tilt of the beds in a direction a little north of west, so that any definite bed is about 200 feet higher at the east margin of the area than it is at the west, but this regional tilt is so greatly obscured by the manner in which the beds are folded and faulted that it is not in the least prominent.

A very conspicuous structural feature is a shallow syncline extending in a nearly straight line for 11 miles from sec. 31, T. 24 N., R. 8 E., in a direction 15° east of north to sec. 10, T. 25 N., R. 8 E. The floor and flanks of this syncline are crossed by no less than 16 faults, all striking between N. 10° W. and N. 32° W. and nearly all with the upthrow on the northeast side of the fault plane. As a consequence of this fault-shattered trough at right angles to the regional tilt of the beds, there is a series of minor anticlines and domes on each side of the syncline and roughly parallel to it. These folds will be described in detail, beginning with the southernmost one of the western series, proceeding northward and then southward along the east side of the syncline. (See fig. 27.)

Equally as remarkable as the structural trough just described is an anticlinal fold which covers a large part of T. 24 N., R. 8 E., and which extends into T. 23 N. on the south and into R. 9 E. on the east. It is shaped like the letter V, with the point of the letter near the north quarter corner of sec. 16, T. 24 N., R. 8 E., and with one limb trending southeastward to secs. 15, 14, and 13 and into T. 24 N., R. 9 E. Between the sides of the V there is a broad and very pronounced syncline, a part of which is now occupied by the valley of Little Hominy Creek and most of which was probably at one time occupied by one of the major streams that drain the region. This large syncline is particularly remarkable because it opens toward the southeast, whereas most of the synclines in the Osage Reservation have their heads to the east and open toward the west. Along the axis of the large anticlinal fold there are four minor anticlines separated by structural saddles. In the detailed discussion which follows the major fold is considered as a unit and is described separately.

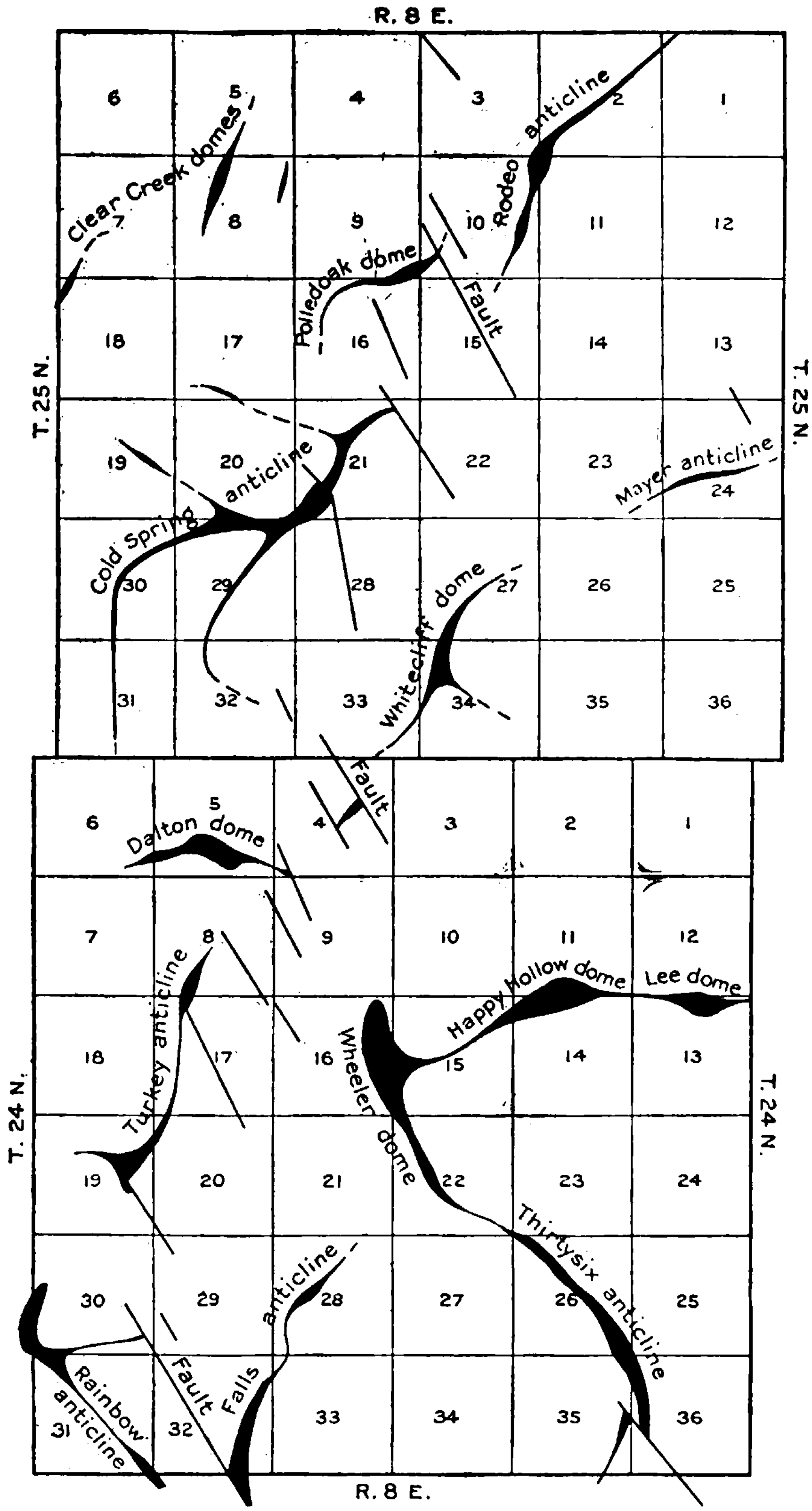
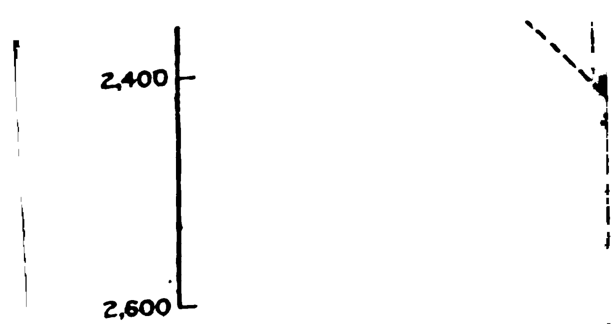


FIGURE 27.—Sketch showing approximate positions of the axes of anticlinal folds in Tps. 24 and 25 N., R. 8 E.



ROCKS UNDERL

ANTICLINES AND DOMES.

RAINBOW ANTICLINE.[1]

The axis of the Rainbow anticline trends northwest across the center of sec. 31, T. 24 N., R. 8 E., athwart the syncline referred to above, which divides the anticline into two distinct parts. The southeastern part continues to rise toward the southeast as the anticlinal axis passes out of the area under discussion into sec. 5, T. 23 N., R. 8 E.

The northwestern portion of the Rainbow anticline is a broad, low dome covering parts of secs. 25 and 36, T. 24 N., R. 7 E., and of secs. 30 and 31, T. 24 N., R. 8 E. The summit of the dome is in sec. 25, and only the eastern and northeastern flanks lie within the townships which are the subject of this report. The closure is less than 20 feet. No tests have been drilled on this fold, but from the presence of the rich oil field 3½ miles southeast of it the inference is justifiable that oil and gas bearing sands are present at this locality. To judge from the general shape and size of the dome, however, it does not appear probable that wells drilled in it will yield nearly so much oil as has been produced from the wells in the more pronounced dome of this neighboring field.

The best location for a test well on the northwestern portion of the Rainbow anticline is a little west of the center of the SE. ¼ sec. 25, T. 24 N., R. 7 E. A well drilled there should strike the "Oswego lime" between 2,100 and 2,200 feet below the surface, and the "Mississippi lime" about 375 feet deeper. It should be drilled to a depth of at least 3,000 feet to be an adequate test. Within R. 8 E. the best location for testing this structure would be at the middle of the west side of sec. 30, T. 24 N. Conditions favoring the accumulation of oil and gas are present throughout the greater part of the W. ½ NW. ¼ and the SW. ¼ sec. 30 and the NW. ¼ sec. 31, T. 24 N., R. 8 E.

TURKEY ANTICLINE.

The axis of the Turkey anticline is sigmoidal and extends from a point near the center of sec. 19 across the NW. ¼ sec. 20 and through the W. ½ sec. 17 and dies out against the southern flank of the Dalton dome, near the center of sec. 8, T. 24 N., R. 8 E. The crest of the anticline is modified by two domelike bulges, each with a closure of little more than 10 feet and each pierced by a fault extended from the axis of the syncline toward the east. Neither has been tested.

[1] In the preceding chapter of this volume (Bull. 686-L) the Rainbow anticline is described in the text (p. 145) as the South Hominy Creek anticline. In the same chapter the name of the North Hominy Creek anticline was, through an oversight, omitted from the map (Pl. XXIII).

The south dome is broad and flat, embracing less than half a square mile, although the accumulation of oil and gas may be influenced by it over a much larger area. The broad, flat terrace underlying all of sec. 18 may be of considerable economic importance, though wells with only a moderate yield are all that can be expected even in its most favorable part. Good places for test wells may be found near the center of the NW. ¼ sec. 20, a little south of the center of the NE. ¼ sec. 19, or in the extreme southwest corner of sec. 17. If the first of these localities is chosen and the well is drilled in the creek bottom it should encounter the Big lime at a depth between 1,800 and 1,850 feet, the Oswego lime somewhere near 2,000 feet, and the Mississippi lime between 2,300 and 2,400 feet.

The north dome on the Turkey anticline covers a much smaller area, centering about a point 1,700 feet east of the northwest corner of sec. 17. This feature might better be described as a warped terrace on the south flank of the Dalton dome. Its importance as a reservoir of hydrocarbons is probably very slight in comparison with that of the larger and higher dome to the north. No prospecting for oil or gas should be attempted there unless the Dalton dome should prove to inclose a productive pool.

DALTON DOME.

The Dalton dome is a much more pronounced uplift than any of those described above, both as regards area and closure. The lowest closed contour embraces an area of nearly a square mile in the southern and western parts of sec. 5, the SE. ¼ sec. 6, the NE. ¼ sec. 7, and along the north side of sec. 8, T. 24 N., R. 8 E. The closure is about 30 feet. The crown of the dome is centered near the middle of the east line of the SW. ¼ sec. 5; there is a secondary bulge in the SE. ¼ SE. ¼ sec. 6.

The size and shape of this dome and the area of gathering ground from which oil may have migrated to form a pool beneath it appear favorable for the development of wells with at least moderate yield. The presence of a dry hole squarely on top of the smaller bulge near the southeast corner of sec. 6 is therefore very much of a disappointment. This well, which was drilled in the spring of 1918, reached a depth of 2,529 feet without encountering more than small "showings" of oil and gas. At the horizon of the Layton sand, as that name is applied in the oil field in the southeast corner of the township, only large volumes of water were encountered. A light show of oil is reported from a sand 250 feet lower; and a limestone penetrated at 1,985 feet, reported as the "Oswego lime," but in reality the Big lime, yielded a "small show" of gas. A short distance below this limestone is a sand—the equivalent of the Wheeler sand of the oil field 6 miles to the southeast—from which a "small show" of oil was obtained. The Fort Scott ("Oswego") limestone carried no oil. At the horizon of the Bartlesville sand 15 feet of "broken sand" which did not show any sign of oil or gas was encountered. The "Mississippi lime," which gave a "very small show" of gas, was penetrated for only 10 feet. The rocks reported by the driller as having been penetrated are shown graphically in Plate XXVI.

Before condemning the Dalton dome, or even before concluding that the sands above the "Mississippi lime" will not yield oil or gas in commercial quantities within its area, at least one other test hole should be drilled. It should be located on the higher and larger bulge in the SW. ¼ sec. 5. The Big lime should be reached here at a depth of about 1,950 feet, the "Oswego lime" at about 2,120 to 2,150 feet, and the "Mississippi lime" at nearly 2,500 feet. The hole should be continued to about 3,100 feet in order to give an adequate test. It is greatly to be regretted that the hole in sec. 6 was not drilled deep enough into the "Mississippi lime" to reach the beds 130 feet and more below its top, which have been proved to yield commercial quantities of oil and gas elsewhere in the Osage Reservation.

COLD SPRING ANTICLINE.

The sinuous crest of the Cold Spring anticline stretches from the NE. ¼ sec. 6, T. 24 N., R. 8 E., northward across secs. 31 and 30, T. 25 N., R. 8 E., bends eastward along the north side of sec. 29 and reaches its highest altitude in the SW. ¼ sec. 21. There it is sheared downward by a crooked fault that extends across it and the adjacent syncline in secs. 28 and 21, but the anticlinal fold continues northeastward nearly to the north line of sec. 21, where it terminates against another but much smaller fault. (See fig. 27.) A branch from this main crest extends southward from the center of sec. 29 to the center of sec. 32; another trends westward from the southern part of sec. 20 to the center of sec. 19; and a third minor flexure crosses the NE. ¼ sec. 20 to the SW. ¼ sec. 17. About 2¼ square miles is included within the lowest closed contour on this anticline, but nearly one-fifth of the township is underlain by beds having the favorable structure pertaining to it. The closure is about 90 feet, but the area from which oil and gas may be drawn probably extends west of the lowest closed contour. The size, shape, and relation to drainage area of the Cold Spring anticline indicate that it is one of the most favorable uplifts for the localization of an oil and gas pool in the region under discussion, and it is difficult to see how the fault which crosses it can materially improve or impair its capacity as a reservoir of hydrocarbons. Unless there is an utter absence of suitably porous strata, or of a source for oil and gas, beneath this anticline, it should yield many wells of moderate production and a few of large flow. Structure favorable for oil accumulation is found in all of sec. 21 except the SE. ¼ and the far northwest corner, all of sec. 20 except the NE. ¼, the SW. ¼ sec. 17, nearly all of secs. 19, 30, and 31, all but the southeast corner of sec. 29, and the northwest corner of sec. 28.

This anticline has not been drilled, although three holes have been sunk in its immediate vicinity. The dry hole in the southeast corner of sec. 16 is exactly in the bottom of the synclinal saddle between the Cold Spring anticline and the Polledoak dome. Its record, as preserved in the archives of the Osage Indian Agency, shows 200 feet of "sand and water" at a depth of 950 feet, immediately below a limestone which was incorrectly identified as the Big lime. This sand probably represents the Layton sand of the oil field in the southeast corner of T. 24 N., R. 8 E. A 55-foot sand was penetrated at a depth of 1,405 feet. Between a limestone series at 1,670 to 1,680 feet, which doubtless represents the Big lime, and the Fort Scott ("Oswego") limestone there is reported to be 65 feet of "slate." Below the Fort Scott limestone only "slate and shells" are recorded until the "Mississippi lime" is reached at 2,284 feet. It was penetrated for only 7 feet. This record is a very poor one, and the information it gives can not be accepted without question. There must be some doubt about the absence of sands between the Fort Scott and the "Mississippi lime." Another well drilled since the completion of the field work on which this report is based is situated on the southwest flank of the Whitecliff dome, in the southeast corner of sec. 33. Gas was encountered in this well at a little more than 1,000 feet below the surface, and oil in commercial quantities was obtained from a 21-foot sand at 1,890 feet. This sand would correspond to either the Peru or Wheeler sand of the drillers, and its presence here lends support to the hope that it is also present beneath the Cold Spring anticline. The third well near this anticline is that, already referred to, which punctures the secondary bulge on the crest of the Dalton dome in sec. 6, T. 24 N., R. 8 E.

Test wells should be sunk at a number of points on the Cold Spring anticline. One should be drilled about 500 feet east and 200 feet north from the southwest corner of sec. 21, squarely on top of the highest point of the fold, where the Big lime may be expected at a depth of about 1,800 feet, the "Oswego lime" at approximately 2,050 feet, and the "Mississippi lime" between 2,400 and 2,500 feet. A good place for a second test is in the SE. ¼ NW. ¼ sec. 21, where the limestones just named should be encountered at depths 75 to 100 feet less than in the first test suggested. A third suggested location is in the SW. ¼ NE. ¼ sec. 19, where depths to the limestones should be about 50 feet greater than in the first test suggested. Still another hole, to complete the thorough testing of this anticline, might be sunk near the center of sec. 29.

POLLEDOAK DOME.

The apex of the Polledoak dome is near the southeast corner of sec. 9, T. 25 N., R. 8 E., and the area embraced within the fold covers approximately 1 square mile, including the N. ½ sec. 16, the SE. ¼ sec. 9, and parts of the SW. ¼ sec. 10 and the NW. ¼ sec. 15. It is difficult to estimate the amount of closure with accuracy. If the long fault that traverses the whole of sec. 15 effectually seals the northeast side of the fold, the closure is about 40 feet, and nearly a half section is included within the lowest closed contour. If this fault does not continue to the oil or gas bearing strata which may be below the surface here, the closure is less than 20 feet and less than a quarter section is included within the lowest closed contour. In either event, the dome is well worth a test, for the dry hole in the syncline to the south, referred to in a preceding paragraph, is no criterion of conditions within the area of this dome.

It is quite likely that at least a moderate yield will be obtained within the area covered by the Polledoak dome. The structure is well defined, the closure is fair in amount, and the area available for drainage into the dome is extensive. The best place for a test well is on the crown of the dome in the SE. ¼ SE. ¼ sec. 9. A well on the table-land there should strike the Big lime at a depth between 1,750 and 1,800 feet, the "Oswego lime" about 250 feet lower, and the "Mississippi lime" between 2,350 and 2,400 feet.

CLEAR CREEK DOMES.

The Clear Creek domes are three small bulges on the surface of a broad terrace which extends from the NE. ¼ sec. 13, T. 25 N., R. 7 E., to the NE. ¼ sec. 5, T. 25 N., R. 8 E. It is possible that the entire area between the 540 and 580 foot contours in this corner of T. 25 N., R. 8 E., may prove to be underlain by gas or oil in commercial quantities, although no wells of more than moderate yield should be expected. The three small domes, however, extend much greater promise than the portions of the terrace beyond their limits. Each has a closure of 10 to 20 feet, and the middle one of the three covers an area of about half a square mile. In view of the magnitude of its drainage area to the west, this largest one of the Clear Creek domes is well worthy of a test, although the results of the test can not be forecast until the Coldspring anticline and the Polledoak dome have been drilled. The test well might be located in the Clear Creek bottoms about 1,700 feet east of the west line and 1,500 feet south of the north line of sec. 8. The Big lime probably lies about 1,800 feet below the surface at that point.

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RODEO ANTICLINE.

Stretching northeastward from the NE. ¼ sec. 15, T. 25 N., R. 8 E., is a broad, low fold—the Rodeo anticline. Nearly 2 square miles in secs. 1, 2, 3, 10, 11, 14, and 15, T. 25 N., R. 8 E., fall within the lowest closed contour on this fold, although the closure is only 30 feet. Two small bulges centering in the NE. ¼ and the SE. ¼ sec. 10 rise above the generally flat summit of this anticline. Structurally it is well adapted for the localization of an oil or gas pool, although its gentle slopes may mean that only moderate yield would be obtained from its wells. The drainage area is less than might be desired. Even though the faults which graze the anticline on the southwest should prove ineffectual as a barrier to the migration of oil and gas, the source of supply from that direction is to some extent cut off by the domes and anticlines just beyond, so that the Rodeo anticline could receive the drainage up the general western dip of the region only through a narrow belt in the N. ½ sec. 10 and the S. ½ sec. 3.

Little light can at present be shed upon the question of the presence or absence of suitable strata which might serve as reservoirs of oil and gas below this anticline and without which the favorable structure will be of no avail. The anticline has not been drilled and none of the closely adjacent folds have been tested. A good place for a test well is probably in the NE. ¼ NE. ¼ sec. 10 about 1,000 feet west of the east line of the section; a second location is near the center of the NW. ¼ NE. ¼ sec. 15. At the location in sec. 10 the Big lime should be struck at a depth of 1,725 feet, the Fort Scott limestone between 1,950 and 2,000 feet, and the "Mississippi lime" between 2,300 and 2,350 feet. The well in sec. 15 would reach the same horizons at depths only slightly less.

MAYER ANTICLINE.

The Mayer anticline is a short fold extending westward across the S. ½ sec. 24, T. 25 N., R. 8 E., into the SE. ¼ sec. 23. There is no closure; the fold is outlined by strong north, west, and south dips, but no east dip occurs. This anticline is therefore of trivial importance in comparison with the other favorable folds here described. Moreover, it is so hedged in by synclinal troughs that the gathering ground from which oil or gas might migrate into it is very small.

Two holes, both dry, are reported to have been drilled on the flanks of this fold. The locations of these wells as shown on the map are only approximate, for neither was found in the course of the field work on which this map is based. No log of the northern well is available, and that of the southern one merely records the presence of sand at 1,656 feet and the total depth of the hole as 1,956 feet. This depth would probably carry the hole only a short distance below the Fort Scott ("Oswego") limestone.

Unless good yields should be obtained on the neighboring anticlinal folds, it would not seem advisable to make further tests on the Mayer anticline. Should such a test prove advisable a good location for it is 1,000 feet north of the south line and 1,000 feet west of the east line of sec. 23, on the plunging tip of the anticline. The well here should reach the Big lime at a depth between 1,600 and 1,700 feet, the Fort Scott ("Oswego") limestone 250 to 300 feet deeper, and the "Mississippi lime" between 2,200 and 2,300 feet.

WHITECLIFF DOME.

The prominent, well-defined dome in the middle of the southern part of T. 25 N., R. 8 E., may be referred to as the Whitecliff dome because of the conspicuous cliffs of light-gray Little Hominy and Deer Creek limestone which nearly surround it. The apex of the dome is in the NW. ¼ sec. 34, and large parts of secs. 33, 28, and 27 lie on its flanks or summit. The closure is about 40 feet, and approximately three-fourths of a square mile lies within the lowest closed contour. Should it prove that the structure of this dome has served to localize an oil or gas pool, it may be expected that the productive area will cover the W. ½ sec. 34, much of sec. 27, the southeast corner of sec. 28, and the eastern part of sec. 33. It may also extend into the NE. ¼ sec. 3, T. 24 N., R. 8 E.

Although the Whitecliff dome leaves little to be desired so far as size and shape are concerned, its relations to the general structure of the whole region are not so favorable for the accumulation of a large pool of oil or gas as might be wished. As it stands on the east side of the long, shallow, fault-shattered syncline which traverses the west side of the township, it may, to a large extent, be cut off from any supply of hydrocarbons that may have moved up the regional dip from the west. This condition will probably result in wells of moderate production, with the possible exception of such as are drilled close to the crown of the dome.

Since the completion of the field work on which this report is based a well has been drilled in the southeast corner of sec. 33, on the southwestern flank of this dome. The well log is not now available, but it is known that oil in commercial quantities was struck in a 21-foot sand at a depth of 1,890 feet. This sand is presumably either the Peru or the Wheeler sand of the oil fields to the east and south. The inference is that wells with greater yield may be obtained in the higher parts of the dome and that either gas wells or fairly large oil wells may be expected in the northwest corner of sec. 34

and the immediately adjacent territory. In estimating the value of the output which may be expected from this dome, the possible presence of the Bartlesville sand and of oil-bearing beds in the "Mississippi lime" below the sand whose presence has been demonstrated by the well just mentioned should be taken into consideration.

The very apex of the Whitecliff dome should be penetrated by a well sunk at a point 1,000 feet east of the west line and an equal distance south of the north line of sec. 34. This well would probably reach the Big lime at a depth of about 1,750 feet, the Fort Scott ("Oswego" limestone 250 or 275 feet deeper, and the "Mississippi lime" at about 2,400 feet.

LEE DOME.

The Lee dome is the easternmost of the separate domes on the axis of a large anticlinal fold which occupies most of the eastern part of T. 24 N., R. 8 E. It is a small rounded swelling, in which the rocks bow upward very gently, and stands on the line between secs. 12 and 13. The closure is but 10 feet, and the area included within the lowest closed contour is only about 80 acres. On the north and south sides of the dome the rocks dip steeply for a long distance into the synclines which border the big anticlinal fold, but on the east and west flanks of the dome the beds lie almost flat.

No drilling has been done on or near the Lee dome, so any guess as to the conditions which underlie it must be based on evidence offered by wells at some distance and is accordingly liable to considerable inaccuracy. To judge from the conditions of the oil field in T. 24 N., R. 8 E., which is about 3 miles south of the Lee dome, the beds most likely to contain oil are moderately shallow sands associated with the Big lime and the Fort Scott ("Oswego") limestone, which are known as the Peru sand and the Wheeler sand in the oil field referred to above. Although the Bartlesville sand may possibly be present in the Lee dome, it is probably either entirely absent or is very thin and can not be expected to be very productive. There is also a possibility that beds in the "Mississippi lime" carry oil and gas at this locality, and any development work that is done on the Lee dome should be thorough enough to determine the nature and oil content of the beds which lie for about 300 feet below the top of the "Mississippi lime."

The structural conditions at the Lee dome would not be considered exceptionally good were it not that this dome is only a part of a very strongly developed anticline which has probably induced the formation of oil pools at any point under its axis where there is appreciable secondary doming.

A good location for a test well is believed to be just east of the quarter corner between secs. 12 and 13. A well located here should strike the Big lime at a depth of about 1,700 feet, the Fort Scott limestone at about 1,900 feet, and the "Mississippi lime" at about 2,300 feet.

HAPPY HOLLOW DOME.

The Happy Hollow dome is a low fold whose crown lies between Happy Hollow and Little Hominy Creek. The highest point on the fold is a little south of the quarter corner between secs. 11 and 14, and from this point the rocks slope gently to the east and to the west until the dip is reversed on the structural saddles that separate the Happy Hollow dome from the Lee dome on the east and from the Wheeler dome on the west. To the north and the south the dip steepens a short distance from the crown of the dome and the beds descend steeply into the large synclines which limit the fold in these directions.

No drilling has been done on the Happy Hollow dome, and as it is 3 miles from any extensive developments, it is not possible to say definitely what oil-bearing beds may underlie its surface. The nearest producting well is on the Wheeler dome, almost 2 miles west of the center of the crown of the Happy Hollow dome, where a single well has been drilled to the horizon of the "Oswego" lime. Several gas sands and at least one oil sand were struck above the Big lime, from which the principal yield comes. On the Whitecliff anticline, about 3 miles north of the Happy Hollow dome, a single well has been drilled; this well found enough oil at the general horizon of the Fort Scott ("Oswego") limestone to make about a 5-barrel well.

The data given above and the conditions in the oil fields in the southeastern part of T. 24 N., R. 8 E. (see p. 167 and Pl. XXIV), indicate that the beds which are most likely to contain gas and oil below the Happy Hollow dome are those which are closely associated with the Big lime and with the Fort Scott ("Oswego") limestone. There is a chance of obtaining some oil from the Bartlesville sand, but the prospects of any great yield from this sand do not look particularly good. There is a very fair possibility that the "Mississippi lime" will prove to contain both oil and gas, and it should be tested thoroughly beneath this dome.

Good locations for testing the Happy Hollow dome are in the bottom of the valley of Little Hominy Creek near the center of the NW. ¼ NW. ¼ sec. 14 and near the center of the NE. ¼ NE. ¼ sec. 14. A well at the first location should encounter the oil and gas bearing beds of the field in sec. 36 at a depth not more than 100 feet greater than in that field. (See Pl. XXIV.) A well at the second location will find these same beds at slightly greater depth.

WHEELER DOME.

The Wheeler dome lies at the tip or point of the V formed by the large anticline in the eastern part of T. 24 N., R. 8 E. The crown of the dome is just west of the quarter corner between secs. 15 and 16, and the lowest closed contour incloses much of the W. ½ sec. 15 and the E. ½ sec. 16. From the crown of the fold the beds dip gently to the east and the south until they reach the axes of the structural saddles in secs. 15 and 22, which separate the Wheeler dome from the Happy Hollow dome on the east and from the Thirty-six anticline on the south. To the north and west the beds plunge toward the bottoms of the major synclines that limit the large anticlinal fold of which the Wheeler dome is but a part. The closure on the Wheeler dome is only about 20 feet, but it seems improbable that the importance of the dome as a source of oil and gas can be judged by this small measurement. When the field work in T. 24 N., R. 8 E., was completed no drilling had been done on the Wheeler dome, but since that time a well in the SW. ¼ sec. 15, a short distance from the crown of the fold, has been drilled to a depth of 1,933 feet, where it was stopped in the Fort Scott ("Oswego") limestone. This well passed through several gas-bearing sands and one oil-bearing sand in the upper 1,000 feet and obtained a heavy flow of gas from the upper part of the Big lime. The total flow is reported to be 12,000,000 cubic feet a day. The well passed through 12 feet of sand just below the Big lime, but no yield is reported from it. The "Oswego" lime was penetrated 12 feet and is gas bearing.

It has been demonstrated that gas-bearing sands underlie the Wheeler dome, and it is very probable that wells bored farther down from the crown of the dome than the well which is giving the present gas yield will find oil as well as gas in some of these sands. This belief is encouraged by conditions in the field about 3 miles southeast of the Wheeler dome, where the shallow sands in some of the wells carry little but gas, whereas in others only a short distance away they yield large volumes of oil.

Besides the prospects of obtaining oil and gas from the shallow sands there is a possibility that the Bartlesville sand underlies this dome and carries oil. In the field just mentioned the Bartlesville sand has been a disappointment, for it is much thinner than it is in the more productive portions of the Osage Reservation and has contributed a comparatively small amount of oil to the total output of the field. On the other hand, a "pay" sand which is either at the horizon of the Bartlesville or only a little lower has yielded tremendous volumes of oil in secs. 8 and 9, T. 23 N., R. 8 E., only about 5 miles south of the Wheeler dome. Accordingly it must be recognized that there is a strong possibility that some beds at the general horizon of the Bartlesville will be found extremely productive under this entire area.

Below the Bartlesville sand is the "Mississippi lime," which has not been really tested by any wells in this general region. However, it is known to carry both oil and gas under favorable anticlinal folds in other parts of the Osage Reservation, and there is good reason to hope that it will prove to be similarly productive below the Wheeler dome.

Good locations for further testing of the Wheeler dome are the center of the SE. ¼ SE. ¼ sec. 16, the center of sec. 16, and the extreme southeast corner of sec. 9. It will also probably be well to test the lower part of the dome by drilling near the center of sec. 22. At these locations the oil and gas bearing beds should lie about 200 feet farther below the surface than they do in sec. 36. (See Pl. XXIV.) Drilling should be continued in these wells until they have penetrated the "Mississippi lime" about 300 feet, unless they find "pay" at less depth. This will call for a total depth of not less than 2,700 feet. There is every reason to believe that the anticlinal structure is more pronounced in the "Mississippi lime" than it is on the surface, and the oil-bearing possibilities of this deep lime should be thoroughly demonstrated.

THIRTY-SIX ANTICLINE.

The Thirty-six anticline is the largest of the separate folds that lie along the axis of the big V-shaped anticline in the eastern part of T. 24 N., R. 8 E. The axis of the Thirty-six anticline runs from a point about 1,000 feet west of the quarter corner between secs. 22 and 23 southeastward through the southwest corner of sec. 23 and the center of sec. 26 and along the west side of sec. 36, where it terminates abruptly against a fault with a throw of about 50 feet which cuts squarely across the anticline. On the south end of this anticline an extensive oil and gas field has been developed; wells with an initial daily production as great as 4,000,000 cubic feet of gas and 400 barrels of oil have been reported, although the average is much less. The fields extend far down the east flank of the anticline toward the syncline that borders the fold on the east. As noted in a preceding paragraph of this report (p. 154), the oil and gas are obtained largely from the Wheeler sand and the "Oswego" lime, reached at a depth between 1,700 and 1,800 feet, but the Peru sand, a little higher in the section, and the Bartlesville sand, reached at a depth of about 2,050 feet, also give fair yields. It is reported that wells drilled since the completion of the field work for this report have obtained very good yields from sands that lie above the Peru sand, but no information concerning the exact position of these sands in the stratigraphic section or the initial production of the wells is available. So far as can be learned no wells have been drilled deeper than 50 feet into the "Mississippi lime," which is not a sufficient depth to test this formation adequately. It is very important that wells be drilled at least 300 feet into the lime below the Thirty-six anticline, as this formation has yielded large volumes of both oil and gas elsewhere in the Osage Reservation, and there are few localities where the geologic structure appears better suited to have brought about an accumulation of oil and gas than under the Thirty-six anticline. The exact effect which the large fault that cuts the beds on the Thirty-six anticline has had upon the oil and gas-bearing strata has not been determined. Thus far no wells with large production have been completed west of the fault, but it can not be said definitely that the fault is the cause of the small yield.

The Thirty-six anticline should be developed by extending the present field to the north and west; it is probably also justifiable to drill a few test wells beyond the productive area. Good locations for these wells are the center of sec. 26, the extreme northwest corner of sec. 26, and the center of the SW. ¼ SE. ¼ sec. 35. At all these locations the beds which are productive in the developed field lie at slightly greater depths below the surface than in the wells that have already been drilled.

FALLS ANTICLINE.

The Falls anticline is a small fold extending from the SE. ¼ sec. 32, T. 24 N., R. 8 E., in a direction a little east of north to the SE. ¼ sec. 21, where it merges with the Little Hominy anticline. Beneath the bed of Hominy Creek the anticlinal fold is crossed by a synclinal saddle which divides it into two parts, each of which is in reality a long, narrow terrace or "nose" extending outward from the lower flanks of a large anticlinal uplift. The northern part of the Falls anticline is a low terrace projected far southward from the side of the Little Hominy anticline and bears a small bulge with a closure of about 10 feet on the outer end of the "step." The southern part of the Falls anticline bears a similar though somewhat more remote relation to the anticlinal fold on which lies the "Osage-Hominy oil field," in and near sec. 9, T. 23 N., R. 8 E.

Neither portion of this fold has been drilled, and no tests should be made here until the location of the oil pools in the adjacent, more pronounced uplifts have been fairly well outlined. Structural conditions beneath the areas included within the 740-foot contour (Pl. XXIV), in secs. 28, 32, and 33, are unquestionably favorable for the accumulation of oil and gas, but only wells of small yield should be expected there. The available gathering ground is small, and the capacity of the fold at best is slight. Good localities for testing its possibilities will be found in the SW. ¼ NE. ¼ sec. 32 and about 300 feet east of the west quarter corner of sec. 28.

Attention may be directed in this connection to the similar warped terrace underlying the SE. ¼ sec. 34. In spite of its unfavorable situation with respect to the probable directions of underground migration of oil and gas, it may possibly have determined the location of a small pool.

UNFAVORABLE AREAS.

It is evident from the foregoing descriptions of anticlinal folds in Tps. 24 and 25 N., R. 8 E., that the greater part of this area lies in a zone of marked deformation. Either the rocks have been subjected to unusual deformational stresses or they have been of less than average competence to resist stresses. In either event it can scarcely be doubted that crustal movements have been localized here for a long time, probably dating from a period preceding that during which the rocks now exposed at the surface were laid down. It should not be forgotten that deposition has been far from continuous in this region; that a break in sedimentation of continent-wide extent occurred after the deposition of the "Mississippi lime" and before that of the "Oswego lime." This break was occasioned or accompanied by notable crustal movements. Accordingly there may well be in the lower strata beneath these townships many wrinkles which do not appear in the exposed formations. General experience in the Osage Reservation in particular seems to indicate that zones of marked deformation are very likely to contain pools of oil and gas, which disregard to some extent the minor structural features apparent in the surface rocks. Accordingly there are few localities in such a zone which are unworthy of a test by drilling.

Certain districts in these two townships, however, appear so unfavorable to oil or gas accumulation that it seems wise to avoid them. Although it is possible that oil and gas may be present beneath these areas, it is most unlikely that commercial production will ever be attained in them. They should be left undrilled until the remainder of the townships has been explored, and even then they should be tested only if the conditions in some adjoining area indicate that they contain the extension of a previously discovered pool.

Among these unfavorable districts is the syncline embraced between the arms of the Little Hominy anticline (Happy Hollow and Lee domes and Thirty-six anticline) in T. 24 N., R. 8 E.; most of the N. ½ sec. 25, the SW. ¼ sec. 24, and the N. ½ sec. 23 lie on the floor or lower slopes of that syncline and should be avoided.

The E. ½ sec. 33, T. 24 N., R. 8 E., bears an analogous relation to the synclinal basin east of the Falls anticline. The SW. ¼ sec. 19, the NW. ¼ sec. 9, all of secs. 1 and 2, and all except the northern margin of sec. 3, T. 24 N., R. 8 E., appear distinctly unpromising. In T. 25 N., R. 8 E., the synclinal basins beneath secs. 12 and 13, the E. ½ secs. 11 and 14, and secs. 25, 26, 35, and 36 place those districts in the same category. The E. ½ sec. 32 and the SW. ¼ sec. 28 should likewise be avoided.

TPS. 20 AND 21 N., R. 12 E.

By Clarence S. Ross.

INTRODUCTION.

The fractional Tps. 20 and 21 N., R. 12 E., constitute an area 12 miles long and about 4 miles wide lying in the southeast corner of Osage County. (See fig. 1.) The city of Tulsa is situated just outside the southeast corner of the area, and Sperry lies a mile east of the northern township.

Hominy and Rock creeks cross the northern part of T. 21 N., R. 12 E., and extensive alluvial bottoms occur along their courses. South of the alluvial areas the country is gently rolling, and much of the township is under cultivation. In the southern part of this township and the northern part of T. 20 N., R. 12 E., there is a rugged timbered area, and along the western border of the southern township rise a number of high bald hills, giving a maximum relief to the region of 440 feet. South and east of the areas just mentioned the township is rolling and only partly timbered. Roads are numerous and fairly good in both townships.

STRATIGRAPHY.

EXPOSED ROCKS.

The rocks that crop out in Tps. 20 and 21 N., R. 12 E. (see Pl. XXVII), comprise about 350 feet of middle Pennsylvanian sediments. Sandstone and limestone form only a small part of the geologic section, shale being greatly predominant, as is shown graphically in figure 28. A few of those beds that are suitable as key rocks are described below for the convenience of those who may wish to do geologic work in the region. These rocks are discussed in order of age, the youngest first, and consist of a shale and thin sandstone series, near the base of which lies a massive sandstone; the Hogshooter limestone, used as the datum in the present investigation; and a group of sandstones, the lowest rocks studied in the region.

Sandstones and shales above the Hogshooter limestone.—Shales predominate in the series above the Hogshooter limestone in this area, but thin sandstones are interstratified with them, and locally a

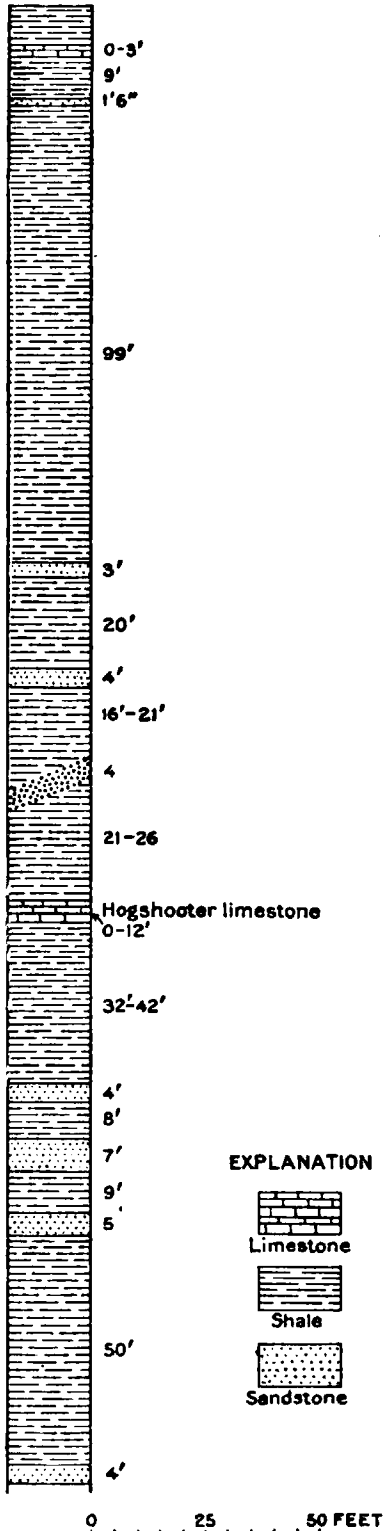


FIGURE 28.—Columnar section of rocks exposed in Tps. 20 and 21 N., R. 12 E.

limestone lies near the top of the group. These shales and interstratified lenticular sandstones appear to be the foreset beds of a delta deposited by a northward-flowing stream in Pennsylvanian time. Their thickness is about 190 feet near the southwest corner of T. 21 N., R. 11 E., but there is evidence of a marked increase in thickness from north to south. This series of beds forms a considerable part of the exposed rocks in the Bald Hill region of T. 20 N., R. 12 E., where they have a steep northward dip that does not correspond to that of the Hogshooter limestone below. These beds were studied and contoured in as much detail as the nature of the exposures permitted and were found to be absolutely valueless for the determination of underground structure. No structure contours, therefore, are shown for the areas where these beds crop out.

A massive sandstone lying at a variable interval above the Hogshooter limestone is exposed over large areas along Rock and Delaware creeks and in the region lying north of Flat Rock Creek. The interval is 25 to 30 feet in T. 21 N., R. 12 E., and the northwest corner of T. 20 N., R. 12 E.; but farther south it increases so greatly that the bed is of little use in contouring the geologic structure.

Hogshooter limestone.—The Hogshooter limestone crops out over a large part of this area, being exposed along both sides of Delaware Creek in T. 21 N., R. 12 E., in the rugged area lying just north and south of the township line, and along a roughly diagonal line running from the northeast to the southwest corner of T. 20 N., R. 12 E. In the southwestern part of T. 20 N., R. 12

E., the maximum thickness is 12 feet, but the limestone thins toward the north and has not been observed in T. 21 N., R. 11 E., or far north of Delaware Creek in T. 21 N., R. 12 E. This limestone is gray on fresh fracture and usually weathers gray, though locally the exposed surface is red. It is immediately overlain and underlain by shale, and the upper layers are usually coarse grained and fossiliferous, containing horn corals and crinoid fragments. The lower layers are finer grained and less fossiliferous than the upper layers. The Hogshooter limestone forms a low ledge in the southern part of the area, but in the northern part it is so thin that it is in many places entirely covered by talus from the sandstone bed above.

Sandstone beds below the Hogshooter limestone.—A group of sandstones and sandy shales lying below the Hogshooter limestone are exposed in the same general area as the limestone. Persistent beds of sandstone lie 42, 54, and 68 feet below the Hogshooter, and a sandstone exposed in sec. 15, T. 20 N., R. 12 E., lies about 125 feet below it. The highest sandstone of the group is about 18 inches thick. It is hard and weathers into angular blocks. The two middle sandstones are massive, light colored, very micaceous, and soft, weathering away rapidly. The lowest sandstone is thin bedded, but the topmost layer forms a persistent outcrop.

ROCKS NOT EXPOSED.

A study of the well logs of the Osage region shows that between the surface beds and the productive oil and gas zone lie sandstone, shale, and limestone, with shale largely predominant. A few of the large number of well logs available are plotted on Plate XXVIII and show graphically the beds encountered in drilling.

The Big lime, whose thickness is 25 to 180 feet, is the first heavy limestone encountered and is usually reported by drillers, but according to the drillers' records, the thickness is so variable that it does not form a good key bed in this region. Below the base of the Big lime is 110 to 190 feet of shale, under which lies the "Oswego lime," 50 to 65 feet thick. The interval between the "Oswego lime" and the Hogshooter limestone is about 890 feet in sec. 20, T. 21 N., R. 12 E., but it increases toward the south and in sec. 22, T. 20 N., R. 12 E., is about 957 feet.

The "Oswego lime" is underlain by 360 to 500 feet of shales and thin sandstones, below which is a series of sands containing the productive oil and gas zones of the district. The top of this productive series lies 1,328 feet below the Hogshooter limestone in sec. 20, T. 21 N., R. 12 E., and about 1,470 feet below this limestone in sec. 22, T. 20 N., R. 12 E., a divergence of nearly 150 feet in about 7 miles. A study of the well records in the eastern part of the Osage Reservation shows that in general there is a divergence between the productive sands and the higher beds from north to south, and this condit:~ prevails in the townships here described.

The productive sand lying at the top of this series is commoı referred to as the Bartlesville sand, and although it may not be t same as the productive sand at Bartlesville, the two sands seem a broad way to occupy similar stratigraphic positions. Gas is coı monly encountered in the upper part of the series, and in some plac the gas sand is separated from the underlying oil-bearing sands l a varying thickness of shale, but in other places there is no sha between the gas and oil sands. The productive zone, including tł gas sand, which is best regarded as part of the Bartlesville, aggr gates 50 to 170 feet in thickness in this area.

The Tucker sand, 10 to 30 feet thick, lies 190 to 240 feet below tł top of the Bartlesville, and the Burgess sand, which is slightl thicker, lies 70 to 90 feet below the top of the Tucker. The entir series embraces the basal portion of the Cherokee shale.

A few wells in this region have penetrated to a limestone gen erally known as the "Mississippi lime." In sec. 33, T. 21 N., R. 1! E., the "Mississippi lime" lies 1,725 feet below the Hogshooter, and in sec. 22, T. 20 N., R. 12 E., it lies about 1,840 feet below. It has been completely penetrated in three wells in this area, and the reported thickness ranges from 187 to 270 feet. This limestone may represent the Boone limestone of northeastern Oklahoma and southeastern Kansas, but without more detailed information than is now at hand such a correlation can not be definitely asserted.

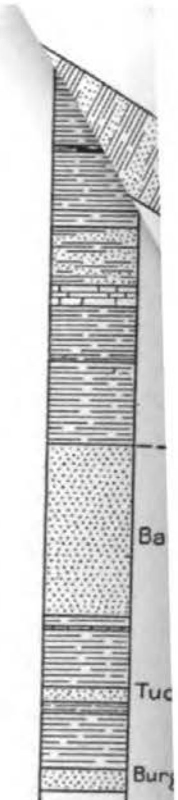
At several localities in the eastern part of Osage County beds below the top of the "Mississippi lime" have yielded oil or gas in commercial amounts, and no well should be regarded as constituting a complete test of a district in this region unless it penetrates the "Mississippi lime" to a depth of 300 feet.

STRUCTURAL FEATURES.

AREAS OF FAVORABLE STRUCTURE.

GENERAL FEATURES.

These townships are part of a large region in which the general dip of the rock beds is westerly or northwesterly. The presence of an easterly dip is therefore significant, for it indicates an upfold that may yield oil in commercial quantities. A study of the records of production in the Osage region shows that in general oil is most likely to occur on the west flank of such an uplift and gas on the crown, and that the east flank is very likely to be dry. The occurrence of dry holes in productive areas seems attributable to locally patchy conditions of the sands. Some of them, however, may rep-



Total depth 1659 fe

resent failure to reach the productive sands. Not all the well logs are available for satisfactory comparison.

In the northern part of T. 21 N., R. 12 E., lies a steeply northwestward-dipping monocline. An area of marked folding extends southeastward from the northern edge of sec. 30, T. 21 N., R. 12 E., across the southern part of this township and involves most of T. 20 N., R. 12 E. In the southern part of T. 20 N., R. 12 E., the beds dip to the northwest, and west of the area of folding the dip is westerly.

The structure is shown on the map (Pl. XXVII) by 10-foot contours, which are based solely on surface data and are drawn on a theoretical bed 300 feet below the top of the Hogshooter limestone.

The area on the northeast comprising Tps. 21 and 22 N., R. 11 E., has been contoured on a theoretical bed 500 feet below the top of the Avant limestone. The interval between the Avant limestone and the Hogshooter limestone in the region near the southeast corner of T. 21 N., R. 11 E., is approximately known, but the interval south of this region is not known, although there is evidence of great thickening to the south. For this reason the two regions can not be contoured on the same beds.

The region here described has been rather thoroughly developed and forms a productive oil field. Geologic work here may possibly be of more value in showing the close relation between upfolds and the accumulation of oil than in indicating possible extensions of the producing territory, and in that way it will prove rather clearly the service that such work can render in the undeveloped parts of the Osage Reservation.

ANTICLINES IN T. 21 N., R. 12 E.

SPERRY FIELD.

In secs. 3 and 10, T. 21 N., R. 12 E., northeast of Sperry, oil is being produced in large amounts, but the structure of the productive rocks can not be determined from surface observations, for all of sec. 3 is covered by alluvium, and the sandstone that crops out in the eastern part of sec. 10 can not be definitely traced toward the southwest. The correlation of this sandstone with the beds to the southwest indicates, however, that the northwesterly dip in sec. 16 gives place in sec. 10 to a westerly dip, a phenomenon which suggests that these sections lie on the western flank of a fold. In the absence of definite structural information no suggestions can be made about possible extensions of the field.

DELAWARE ANTICLINE.

A rather broad, flat fold on Delaware Creek extending from the northern parts of secs. 29 and 30, T. 21 N., R. 12 E., southward to the township line is here called the Delaware anticline. It lies in the SW. ¼ sec. 29, the eastern part of sec. 31, and the western part of sec. 32, being outlined by the 460-foot contour, and has a low crown in the southeast corner of sec. 31 inclosed by the 470-foot contour. The northern brow extends into the southeast corner of sec. 19, beyond which the beds dip steeply to the northwest for a considerable distance. Near the center of sec. 32 is a shallow closed syncline outlined by the 450-foot contour.

Alluvium prevents accurate mapping of the western part of sec. 30 and the northwestern part of sec. 31, but a small terrace appears to lie on the west flank of the Delaware anticline in this region.

The Delaware anticline, being a part of one of the most productive oil fields of Osage County, has been rather thoroughly developed, and the areas of most favorable geologic structure have been drilled. Possible extensions of the field have been outlined by drilling operations, but geologic work indicates that a few more wells may be expected on the northern brow of the anticline in the southeastern part of sec. 19 and the southwestern part of sec. 20, on the western flank in secs. 30 and 31, and in the southern part of secs. 31 and 32.

NORTHEASTERN EXTENSION OF THE BALD HILL DOME.

A terrace extends from the northeastern flank of the Bald Hill dome in sec. 4, T. 20 N., R. 12 E., northeastward across the southeastern part of sec. 33 and the western part of sec. 34, T. 21 N., R. 12 E. A small crown in the eastern part of sec. 33 is marked by the closure of the 520-foot contour.

The western part of sec. 33 has been developed, and a few dry holes near the center of the section are reported, but it is possible that productive wells may be drilled in the eastern part of sec. 33 and the western part of sec. 34.

ANTICLINES IN T. 20 N., R. 12 E.

BALD HILL DOME.

The Bald Hill dome occupies most of secs. 4, 5, 8, and 9, T. 20 N., R. 12 E., and is the largest uplift in the area and one of the most pronounced domes in the Osage Reservation. It has a closure of about 70 feet, is roughly pear-shaped and rather symmetrical in outline; and is marked by a series of terraces on its flanks. The rocks dip westward from the crown of this dome for 2 miles, but farther west the structure is obscured by unconformable delta deposits of Pennsylvanian age and the position of the synclinal axis can not be determined from surface data. On the south, about 2 miles from the crest of the dome, there is a large saddle, and on the southeast, at about an equal distance from the crown, there is a closed syncline. On the northeast a saddle which trends northwest from the southeast corner of sec. 4 separates the Bald Hill dome from a low anticline in sec. 3. The Delaware anticline, described above, lies northwest of the dome.

The dip of the beds on the flanks of the Bald Hill dome is shown in figure 29, a cross section in which the horizontal scale is equal to the vertical scale. This section serves to emphasize the slightness of the dips that are necessary to allow the accumulation of oil in this region.

The Bald Hill dome has been rather thoroughly developed, as all of sec. 4, part of sec. 5, and most of secs. 8 and 9 have been drilled. Dry holes in secs. 3, 7, 18, 17, 16, 21, 15, and 10 almost encircle the dome and make any large extension of the producing area doubtful. Oil production, however, may be considerably increased in sec. 5, and the productive area may be extended into the eastern parts of secs. 6 and 7. An increase in the number of wells in the southern parts of secs. 8 and 9 and the northern parts of secs. 16 and 17 is also probable. On the east some new wells in secs. 3 and 10 may be

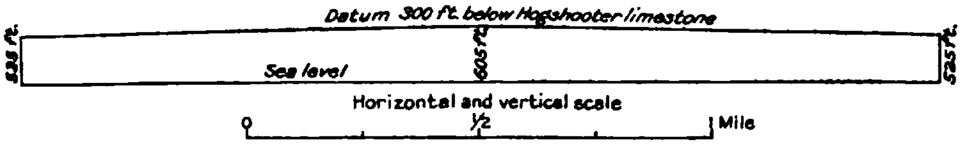


FIGURE 29.—Sketch showing dip of beds on Bald Hill dome.

expected. The reported dry holes in the southeastern part of sec. 9 are in a low saddle and do not preclude the possibility that the higher structure in sec. 10 may yield oil.

FOLD IN SEC. 22.

Secs. 15 and 22 appear to lie on the northwestern flank of a fold which extends into the township to the east but which is obscured by alluvium. The syncline in the northwestern part of sec. 15 probably prevents much extension of the productive area in that direction, and a series of dry holes along the southern border of sec. 22 seems to limit productive territory there. A slight westward extension of the producing area is possible in the eastern part of sec. 21 and the southeastern part of sec. 16.

AREAS OF UNFAVORABLE STRUCTURE.

The alluvium of Hominy Creek covers most of the northern tier of sections in T. 21 N., R. 12 E., and consequently the structure in these sections is mostly unmapped, but work in the township to the west indicates that a syncline extends into the southern part and a small anticline into the northern part of sec. 6, T. 21 N., R. 12 E. It is possible and indeed probable that the monocline mapped south of the alluvium-covered area along Hominy and Rock creeks extends northward under this alluvium-covered area. Nothing, however, can be learned about the oil possibilities of this area from surface observations. The central part of the township is an area of steep monoclinal dip that is not likely to produce notable amounts of oil, as is shown by the dry holes drilled in secs. 9, 16, 17, 18, 20, and 21 and the northern parts of secs. 27 and 28.

The delta beds of Pennsylvanian age prevent accurate structure mapping of the western border of T. 20 N., R. 12 E., and little can be said about the oil possibilities in that region.

The southern part of T. 20 N., R. 12 E., lies on a westward-dipping monocline. It is said that oil wells of minor production and a few small gas wells have been obtained in this area, but dry holes are much more numerous than producing wells, and it seems likely that the area will only yield a local and scanty supply of oil.

PRODUCTION.

In these townships the initial daily production reported ranges from a few barrels up to 150 barrels. The average of reported initial production in the region of the Delaware anticline is about 45 barrels, and that in the area of the Bald Hill dome nearly 40 barrels. Drilling commenced in 1908 and continued to 1917, but more wells were drilled in 1914 than in any other one year. By the end of 1917 the average production for the whole area had dropped to about 10.5 barrels per well. The present rate of production seems to be rather well maintained.

The areas of most favorable geologic structure have all been developed, and it is probable that the initial production of future wells will be smaller than that of those heretofore brought in.

Almost all the oil wells of this region derive their oil from the Bartlesville sand, but it is reported that two wells in sec. 3, T. 21 N., R. 12 E., had an initial daily production of nearly 100 barrels from the "Mississippi lime." Some wells have been drilled to the "Mississippi lime" on the flanks of the Bald Hill dome, but nearly all these wells had been dry in the Bartlesville sand. There is no record of a thorough test of the "Mississippi lime" in a favorable area on either the Delaware anticline or the Bald Hill dome.

The distribution of gas wells in this region is somewhat anomalous. Both oil and gas are found near the crown of the Bald Hill dome, and gas is reported from the flanks of this dome and the Delaware anticline. Gas is derived from beds at various horizons, but only a very incomplete record is at hand. The largest yield seems to be derived from the Bartlesville sand or from the gas sand which is usually the upper part of the Bartlesville, but incomplete data prevent a study of gas production in this area.

TPS. 21 AND 22 N., R. 11 E.

By Clarence S. Ross.

INTRODUCTION.

The area included in Tps. 21 and 22 N., R. 11 E., lies in the southeastern part of the Osage Reservation and in the eastern part of the Hominy quadrangle. (See fig. 1.) It may be reached from Skiatook and Sperry, on the Midland Valley Railroad, about 4 miles to the east. Two major roads run west from these towns, following the valleys of Hominy and Delaware creeks, but the minor roads are very poor, and much of the area is difficult of access. The entire area is hilly and has a maximum relief of 400 feet. Most of the ridges are timbered, and farming is confined to the alluvial bottoms of the larger creeks.

The areal geology of the Hominy quadrangle has been mapped on a scale of 2 miles to the inch in cooperation with the Oklahoma Geological Survey. The detailed structural examination of Tps. 21 and 22 N., R. 11 E., was made in March, April, May, and June, 1918, by the writer, Sidney Powers, W. S. W. Kew, and P. V. Roundy. All the mapping was done with plane table and telescope alidade.

STRATIGRAPHY.

EXPOSED ROCKS.

The rocks exposed at the surface in this area belong to the middle Pennsylvanian, and consist of sandstone, shale, and limestone, aggregating about 700 feet in thickness. Shale predominates, but sandstone and limestone form the prominent rock exposures.

A few of the strata that may be used as key beds will be described for the benefit of those who may wish to do geologic work in the region. These rocks will be discussed in order of age, the youngest first. The Clem Creek is the highest persistent sandstone in the area, and below it is a group of limestones that weather red, interstratified with sandstones; a group of massive sandstones; and a thick shale. Below the shale lies the Avant limestone, which has been used as the datum in field work; shale; the Dewey limestone; a very thick shale; a sandstone series; a massive sandstone; and the Hogshooter limestone, the lowest key bed of the region. (See Pls. XXIX and XXX and fig. 30.)

Clem Creek sandstone.—The Clem Creek sandstone, first described by Emery,[1] is the most widespread sandstone in the region. It is exposed on both sides of the plateau north of Hominy Creek in T. 22 N., R. 11 E., and along the plateau between Tall Chief and Turkey creeks in T. 21 N., R. 11 E. The sandstone is massive, generally forming a ledge 6 to 8 feet thick, but a second bench is commonly present 12 to 14 feet below the top. Weathering gives it a peculiar hummock-like surface upon which vegetation is commonly sparse. The interval from the Clem Creek sandstone to the Avant limestone, which is the best key rock of the region, is about 202 feet in the northeast corner of T. 21 N., R. 11 E., and increases to a maximum of 271 feet in sec. 32 of the same township. South of this section the interval decreases rapidly, and in sec. 20, T. 20 N., R. 11 E., it is only 180 feet. The variation of interval between the Clem Creek sandstone and the Avant limestone occurs in the shales that lie immediately above the Avant, and this large convergence is an important obstacle to geologic work in this region. The line of outcrop of the Clem Creek sandstone is indicated on the maps (Pls. XXIX and XXX).

Beds between the Avant limestone and Clem Creek sandstone.—In the northeastern part of T. 22 N., R. 11 E., two siliceous limestones that weather dark red are widely distributed, and locally a third bed of similar character is present below these. The highest of these limestones lies about 44 feet below the Clem Creek sandstone and 154 feet above the Avant limestone, the middle one about 132 feet above the Avant, and the lowest 116 feet above the Avant. Their outcrops are not continuous and they grade laterally into sandstones. In the southwestern part of this township the same limestones, here also locally grading into sandstones, crop out, and the interval from the Avant to the highest is 227 feet in sec. 32, an increase of 73 feet. The intervals between the limestones and the Clem Creek sandstone, though variable, are about the same as in the northeastern area just mentioned. The three limestones are not all found in any one section; two are only locally present, and in some areas all three are replaced by sandstones. This irregularity of occurrence and the absence of distinctive characteristics render their recognition difficult, and in part of this area the heavy sandstones interstratified with the limestones must be used in geologic work.

[1] Emery, W. B., report on T. 23 N., R. 11 E.; Tps. 22 and 23 N., R. 12 E.: U. S. Geol. Survey Bull. 686–B, 1918.

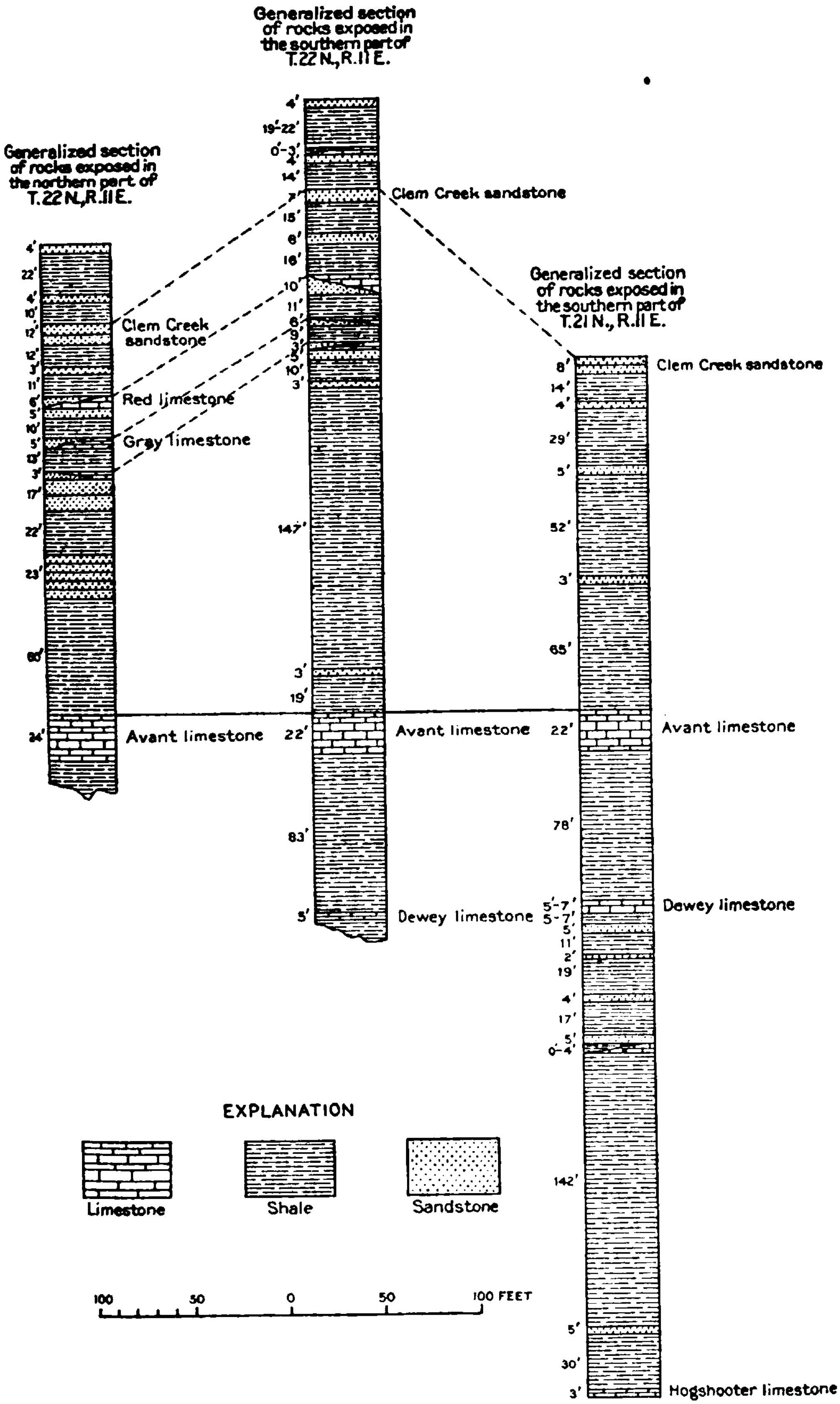


FIGURE 30.—Columnar sections of rocks exposed in Tps. 21 and 22 N., R. 11 E.

Below the limestones there is a series of beds of varying thickness in which sandstone predominates. In the northeastern part of T. 22 N., R. 11 E., the most prominent ledge-making sandstone is about 83 feet above the Avant, and other less persistent sandstones lie between this bed and the Clem Creek sandstone.

Along Hominy Creek in the western part of T. 22 N., R. 11 E., a massive sandstone is exposed near the base of the sandstone group. The interval between this sandstone and the Avant limestone is 187 feet in sec. 33, T. 22 N., R. 11 E., but it decreases rapidly to the north.

In the central part of T. 21 N., R. 11 E., a heavy sandstone that holds up the prairie plateau lies about 185 feet above the Avant limestone, but its correlation with the rocks exposed north of Hominy Creek is not known.

Immediately above the Avant limestone there is an interval of shale varying from 60 to 170 feet in thickness. Locally sandstone beds crop out, but over most of the area the thin sandstones interstratified with the shale do not form continuous exposures.

The line of outcrop is not indicated on the maps (Pls. XXIX and XXX) for any bed lying between the Clem Creek sandstone and the Avant limestone.

Avant limestone.—The Avant limestone crops out in the eastern and southeastern parts of T. 22 N., R. 11 E., and along a roughly diagonal line running from the northeast to the southwest corner of T. 21 N., R. 11 E. In the northern township it is a gray fossiliferous limestone 22 to 27 feet thick. The lower part is massive; but the upper part, 3 to 5 feet thick, is platy and contains numerous fragments of crinoid stems and Bryozoa.

In T. 21 N., R. 11 E., the Avant limestone undergoes a striking change in character and appearance. In the northeast corner of the township the upper, platy, crinoid-bearing beds are absent, and the lower part is fossiliferous and gray, except for a layer 18 to 20 inches thick at the top which weathers brick-red. Toward the southwest the typical gray color of the limestone is progressively replaced by red, fossils become less common, and the thickness decreases. In the southwest corner of the township the red color of the weathered surface extends throughout the limestone, which is here sandy and conspicuously cross-bedded and about 15 feet thick. The Avant limestone throughout most of its extent forms an escarpment, and because of this and its distinctive character it is the best key bed in the region. Its top was therefore used as the datum in the field work.

Dewey limestone.—The Dewey limestone is separated from the Avant by 100 to 105 feet of shale containing thin beds of sandstone. The predominant color of the limestone is gray, but some of the layers weather to brownish-red; fossils are common, especially near the top. Its thickness is not over 3 feet in the southeastern part of T. 22 N., R. 11 E., but is 7 feet in the southern part of T. 21 N., R. 11 E. The outcrop is commonly covered by talus from the Avant escarpment above. The Dewey limestone was used as a key bed in the field, but its outcrop lies close to that of the Avant and has not been marked on the maps.

Sandstones and shales below the Dewey limestone.—Immediately below the Dewey limestone is a group of sandstone beds about 75 feet thick which were used as key beds but which are not indicated on the maps (Pls. XXIX and XXX). The topmost bed of this group lies 12 to 15 feet below the Dewey and is the heavy sandstone that caps the isolated hill near the southwestern part of sec. 24, T. 21 N., R. 11 E., and occurs in a larger area in the southern parts of secs. 26 and 27. South of Delaware Creek in secs. 33 and 34 it is the highest sandstone of the series. The second and third sandstone benches of this group lie 49 and 70 feet below the Dewey limestone and are well exposed in secs. 33 and 34.

Below the sandstones just described is a series of shales and thin sandstones that appear to be forest beds of a delta deposited by a northward-flowing stream in Pennsylvanian time. In this part of the geologic section the beds have a steep north dip that does not correspond to the dips in the beds above and below, and no work in structural geology can be based upon them in the southeastern part of T. 21 N., R. 11 E., where they form a considerable part of the exposed section.

From 25 to 40 feet above the Hogshooter limestone and about 325 feet below the Avant is a massive sandstone 2 to 3 feet thick. It forms the dip slope west of the schoolhouse in the eastern part of sec. 25, T. 21 N., R. 11 E., and crops out along Delaware Creek in secs. 35 and 36. The variation in the interval between the sandstone and the Hogshooter limestone becomes greater in the area to the south.

Hogshooter limestone.—The Hogshooter limestone is exposed in a few places in the southeast corner of T. 21 N., R. 11 E. Its outcrop is not continuous, as this limestone thins to the north and vanishes in this region. The Hogshooter is a coarse-grained gray limestone, containing fragments of crinoid stems. Its maximum thickness is 3 feet, and the interval between it and the Avant is about 356 feet.

ROCKS NOT EXPOSED.

A study of the logs of wells drilled in this area shows that between the surface beds and the productive oil and gas zone lie sandstone, shale, and limestone, with shale largely predominant. This is seen in Plate XXXI, which shows graphically the rocks as reported by the driller in the logs of four selected wells in this area.

The Big lime of the drillers, being the first heavy limestone below the Avant, is easily recognizable. The reported thickness of this limestone ranges from 25 to about 100 feet. In sec. 9, T. 22 N., R. 11 E., it lies 917 feet below the Avant limestone, and in sec. 27, T. 21 N., R. 11 E., it lies 1,168 feet below the Avant limestone. The top of the Big lime is gas bearing in parts of this area.

Below the Big lime is 110 to 160 feet of shale, under which lies the "Oswego lime," 50 to 65 feet in thickness. This limestone is about 1,105 feet below the Avant limestone in sec. 9, T. 22 N., R. 11 E., 1,146 feet below in sec. 12, T. 21 N., R. 11 E., 1,288 feet below in sec. 27 of the same township, and 970 feet below in sec. 12, T. 22 N., R. 10 E.

The "Oswego lime" is underlain by 350 to 440 feet of shales and thin limestones, of which the only good marker is the Pink lime of the drillers, 1,350 to 1,520 feet below the Avant limestone.

A series of sands lying 130 to 160 feet below the Pink lime contains the productive oil and gas zones of the district. The top of this productive series lies 1,480 feet below the Avant limestone in sec. 9, T. 22 N., R. 11 E. In sec. 12, T. 21 N., R. 11 E., the interval is 1,576 feet, in sec. 27 it is 1,720 feet, and in sec. 12, T. 22 N., R. 10 E., it is 1,410 feet.

In the Bartlesville area the productive sand lies about 1,350 feet below the top of the Avant limestone, and in sec. 26, T. 23 N., R. 11 E., according to Emery,[1] the interval is 1,440 feet. Thus the well records show a distinct thickening toward the south of the strata lying above the "Mississippi lime."

Any productive sand in this zone is commonly referred to as the Bartlesville sand, and although it may not be the same as the productive sand at Bartlesville, the sands seem in a broad way to occupy similar stratigraphic positions. Gas is commonly encountered in the upper part of the series, and in some places the gas sand is separated from the underlying oil sands by a varying thickness of shale, but in other places there is no shale between the gas and oil bearing parts of the series. The productive sand aggregates 50 to 160 feet in thickness in this region.

About 190 feet below the top of the Bartlesville sand there is usually found a thinner sand called the Tucker, and 55 to 65 feet lower is the Burgess sand. In this region these sands, including the Bartlesville, form the basal portion of the Cherokee shale—that is, of the Pennsylvanian.

A few wells in this region have penetrated to a limestone generally known as the "Mississippi lime," which lies about 1,660 feet below the Avant limestone in the northern part of the region and

[1] Emery, W. B., op. cit.

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about 1,850 feet below in the southern part. West of this area, in sec. 12, T. 22 N., R. 10 E., the interval from the Avant limestone to the "Mississippi lime" is 1,523 feet. The thickness of this limestone as reported from three wells in Tps. 20 and 21 N., R. 12 E., ranges from 190 to 210 feet. It may represent the Boone limestone of northeastern Oklahoma and southeastern Kansas, but without more detailed information than is now at hand such a correlation can not be definitely made.

Beds below the top of the "Mississippi lime" have yielded oil or gas in commercial amounts at several localities in eastern Osage County, and no well should be regarded as constituting a complete test of a district in this region unless it penetrates the "Mississippi lime" to a depth of 300 feet.

STRUCTURAL FEATURES.

AREAS OF FAVORABLE STRUCTURE.

GENERAL FEATURES.

This area is part of a large region where the general dip is westerly or northwesterly. The presence of an easterly dip is therefore significant, for it indicates an upfold that may yield oil in commercial quantities. A study of the records of production in the eastern part of the Osage region shows that oil is most likely to occur on the west flank of such an uplift and gas on the crown, and that the east flank is more likely to be dry.

In general there is a westerly dip in T. 22 N., R. 11 E. A zone of close folding extends diagonally across the northwestern part of the township and northward into T. 23 N., R. 11 E. On the southeast a large pitching syncline extends across the township. Faulting has occurred in the eastern part of the township, and faults in the southern part extend across the township line into T. 21 N., R. 11 E. The southeastern part of the township is an area of open structure.

The greater part of T. 21 N., R. 11 E., is a steeply northwestward-dipping monocline relieved by a few minor irregularities. An area of marked faulting occurs in the northern part of the township in secs. 3 and 4, T. 21 N., R. 11 E. A fault in sec. 31 crosses into sec. 5, T. 20 N., R. 11 E.

The structure is shown on the maps (Pls. XXIX and XXX) by 10-foot contour lines which are based solely on surface data and are drawn on a theoretical bed 500 feet below the top of the Avant limestone.

The area on the southeast comprising Tps. 20 and 21 N., R. 12 E., has been contoured on a theoretical bed 300 feet below the top of the Hogshooter limestone. The interval between the Avant limestone and the Hogshooter limestone is approximately known for the region near the southeast corner of T. 21 N., R. 11 E., but the interval farther south is not known, although there is evidence of great thickening to the south. For this reason the same bed can not be used for contouring in the two regions.

ANTICLINES IN T. 22 N., R. 11 E.

SOUTH BROWN ANTICLINE.

The most promising upfold in T. 22 N., R. 11 E., lies in secs. 4, 8, and 9 and is called the South Brown anticline. A similar anticline in sec. 33, T. 23 N., R. 11 E., forming a part of the same broad uplift as the South Brown anticline, has been described by Emery[1] as the Brown anticline. The South Brown anticline is outlined by the 210-foot contour and has a closure of 40 feet, but it is in reality a part of a much larger fold that extends toward the north and west and is outlined by the 190-foot contour. On the north a saddle-like syncline separates it from the Brown anticline. On the northeast lies a deep closed syncline, south of which a long nose extends from the southeastern flank of the South Brown anticline northeastward across secs. 10 and 3 and is separated from a small dome in sec. 2 by a low saddle. From the southern flank a smaller nose extends into secs. 21 and 20.

The South Brown anticline offers great promise as productive oil territory. A group of gas wells on the crown tap a gas sand in the Big lime but do not reach the Bartlesville sand. A well drilled to the "Mississippi lime" in the NE. ¼ sec. 9, far down the east flank, showed a trace of oil in spite of its poor location, and a well far down the south flank, on the west side of the nose in the northeast corner of sec. 20, has recently been brought in with a reported production of 25 barrels from the Bartlesville. On the southeast flank of the Fox dome, 2 miles to the northwest, in secs. 5 and 6 of this township, wells are producing from territory that is structurally less favorable. The eastern parts of secs. 5 and 8 and the northeastern part of sec. 17 are favorable areas for the production of oil, and locations recommended for test wells are indicated on the map (Pl. XXX). Oil is likely to be present also in the southern part of sec. 9 and a large part of sec. 16. The higher parts of the fold in secs. 4 and 9 yield gas from the Big lime, and it is probable that the lower sands will yield gas, but oil may be found in them.

The nose extending across secs. 10 and 2 lies on the east flank of this anticline and a deep closed syncline lies to the northwest. This greatly limits the gathering area and makes even the small dome in sec. 2 rather unpromising as a source of oil.

[1] Emery, W. B., op. cit.

FOX DOME.

The crown of the Fox dome, which lies in sec. 31, T. 23 N., R. 11 E., has been described by Emery;[1] but the south flank extends into sec. 6, T. 22 N., R. 11 E. The western part of sec. 5 and the eastern part of sec. 6 have been drilled, and the presence of oil there has been demonstrated. The southern limit of the productive area has been delineated by a series of dry holes in the southern part of sec. 6, but productive territory may be expected in the northern half of the section west of the tested area.

CEDAR BLUFF DOME.

An elongated dome of much promise lying in secs. 18 and 19 near the mouth of Turkey Creek has been called the Cedar Bluff dome. Oil is being produced far down the west flank, in secs. 13 and 24, T. 22 N., R. 10 E., but favorable locations on the south and west flanks in T. 22 N., R. 11 E., have not been tested. Locations recommended for test wells are indicated on the map (Pl. XXX). The crown of the dome is most likely to yield gas but may yield oil.

LAKE VIEW DOME.

South of the Lake View School, in T. 22 N., R. 11 E., lies a sharp upfold which has been called the Lake View dome. It covers all of sec. 33, and extends a short distance into secs. 3 and 4, T. 21 N., R. 11 E. It is bounded on the east by a fault that has a maximum throw of 50 feet. The effect of such a fault is not definitely known, but it does not seem probable that it would affect the accumulation of oil unfavorably. A dry hole just east of the fault in sec. 34 is in so unfavorable a location that it does not in the least discredit the area west of the fault. The most favorable location for a test well is indicated on the map (Pl. XXX), but much of sec. 33 may prove to be productive territory.

In sec. 32 a small terrace forming the west flank of the Lake View dome and the north flank of the Edgewood dome may be productive. A good location for a test well would be near the center of the NW. ¼ sec. 32.

STRUCTURE IN SEC. 13 AND ADJACENT SECTIONS.

The rocks in secs. 12 and 13 are broken by two parallel faults, and the resultant structure is complex. Between the faults the rocks have been folded down into a syncline, and east of the eastern fault the structure is also in part synclinal. West and north of the faults, however, the structure is anticlinal, and in the western part of sec. 12 there is a closure of more than 10 feet against a fault. These

[1] Emery, W. B., op. cit.

structural features are shown graphically on Plate XXX to which attention is called in this connection. It seems possible that oil may have accumulated in the western part of sec. 12 and the eastern part of sec. 11, in what is in effect an anticline, and it also seems possible that the anticlinal nose which is strongly developed in the SW. ¼ sec. 1 may have influenced the accumulation of oil in that area. The only test that has been made of this fold is that of the Barnsdall Oil Co. in the NE. ¼ sec. 14, which proved a dry hole. This well was drilled to the "Mississippi lime" without obtaining oil or gas. A single dry hole does not necessarily condemn a fold, however, and it is thought that a test of the structurally higher area in the W. ½ sec. 12 west of the faults should be made before the area is definitely classed as without value for oil. It is also possible that a well drilled in the southeast corner of sec. 1 may yield oil.

ANTICLINES IN T. 21 N., R. 11 E.

SCARP ANTICLINE.

In secs. 1, 12, and 13, T. 21 N., R. 11 E., is a low uplift which has been called the Scarp anticline. It is outlined by the 350-foot contour, and two low crowns are formed on it by closures of the 360-foot contour. The south flank is a broad terrace lying in the northwestern part of sec. 13, and the north flank is a terrace lying in sec. 1 and the southern part of sec. 36, T. 22 N., R. 11 E. On the east the anticline is limited by a shallow syncline, and on the west there is a steep westerly dip. A well with showings of oil and gas is reported in the NE. ¼ sec. 12 on the east flank of the anticline, which indicates that gas would probably be found on the higher parts of the fold and that oil is to be expected in wells on the west flank. The most favorable areas lie in the western part of sec. 1, the eastern parts of secs. 2 and 11, the northwestern part of sec. 12, and the northeast corner of sec. 14 and adjacent parts of sec. 13. Locations recommended for test wells are indicated on Plate XXIX.

EDGEWOOD DOME.

A low uplift whose crest is in the western part of sec. 5 has been called the Edgewood dome. It is outlined by the 170-foot contour and the 180-foot contour is the only other one to close. On the east lies a shallow syncline, on the southwest is a narrow pitching syncline, and on the west and northwest the rocks dip northwest. The area in which it may be possible to obtain oil includes the western part of sec. 5, the eastern part of sec. 6, and a small tract in the southern part of sec. 32, T. 22 N., R. 11 E. The most promising location for a test well is thought to lie in the eastern part of sec. 6.

RED BLUFF ANTICLINE.

The Red Bluff anticline, in the southwestern portion of the township, is a large fold, separated from the Edgewood dome by a syncline. The main anticline runs from the southern part of sec. 20 southwestward across sec. 29 and into sec. 31, where a fault cuts it near the end. The highest crown is marked by the 300 and 310 foot contours, which close against a fault. The 290-foot contour forms a low crown near the center of sec. 29 and another crown in the southwestern part of sec. 20. Close to the west flank the 280-foot contour forms another low crest not far from the center of sec. 30. The northwestern brow of the anticline is a broad terrace that runs from the southern part of sec. 20 across the northwestern part of sec. 29 and ends in the southeastern part of sec. 30. On the west the beds dip to the northwest, and on the southeast there is a long, shallow syncline, beyond which the beds dip to the northwest. On the north a large pitching anticlinal nose extends from sec. 20 across sec. 17 into sec. 8, and a pitching syncline lies northeast of the anticline.

The northwest flank of the Red Bluff anticline offers excellent possibilities for oil development. The area in which oil may be obtained probably includes the eastern part of sec. 19, the western part of sec. 20, a small area in the northwest corner of sec. 29, most of sec. 30, and the part of sec. 31 west of the fault. This fault has a small throw in sec. 31 and probably would not have an unfavorable influence on the accumulation of oil. Along the crest gas is more likely to be found than oil.

The entire area outlined is not equally favorable for yielding oil, and the most promising locations for test wells lie on the northwest flank of the main anticline in secs. 19 and 20, on the west flank in sec. 30, and on the southwest flank in sec. 31. The northeast flank could be best tested in the southeastern part of sec. 20. These locations are indicated on the map (Pl. XXIX).

ANTICLINAL NOSE NORTH OF RED BLUFF ANTICLINE.

An anticlinal nose extends from the northern brow of the Red Bluff anticline in sec. 20, T. 21 N., R. 11 E., northward across secs. 7, 17, 18, 19, and 20, and is separated from the Edgewood dome by a saddle in sec. 8. East of the northward-pitching nose a pitching syncline trends in the same direction. The convergence between the higher beds and the Avant limestone accentuates the north dip on the nose and syncline, and for this area elevations based on higher beds are reduced to an Avant datum.

The most favorable locations for test wells on this nose lie in the western parts of secs. 17 and 20. (See Pl. XXIX.)

AREAS OF UNFAVORABLE STRUCTURE.

In view of the spotted distribution of the producing wells in this general region, it would be hazardous to state that certain structural features in this area are not favorable for oil. It seems unlikely, however, that commercial quantities of oil will be found in the major synclines, such as that in secs. 21 and 22, the northern parts of secs. 23, 28, and 29, and the southern parts of secs. 14, 15, 20, and 30, T. 22 N., R. 11 E.; that in sec. 7; or the deep closed syncline in the western part of sec. 3 and the eastern part of sec. 4. In T. 21 N., R. 11 E., the synclinal area extending from sec. 4 across the eastern parts of secs. 8 and 17 and the western parts of secs. 9, 16, and 21, is not likely to yield a large quantity of oil.

An examination of records of production in eastern Osage County shows that in general oil is not likely to occur in monoclinal areas such as that in the southeast corner of T. 22 N., R. 11 E. Most of the southeast half of T. 21 N., R. 11 E., is a monocline dipping steeply to the northwest and can not be considered the most favorable territory for oil production. West of the uplift in the western part of this township the dip is west, and therefore the western parts of secs. 6, 7, 18, and 19 should be considered slightly unfavorable.

The effect of faulting on the accumulation of oil is difficult to foretell, but the faulted areas in secs. 12 and 13, T. 22 N., R. 11 E., and secs. 3 and 4, T. 21 N., R. 11 E., can hardly be considered favorable territory.

In sec. 36, T. 21 N., R. 11 E., the delta deposits of Pennsylvanian age prevent accurate mapping of the structure, but in general a north dip is indicated, and dry holes in the southeast corner of sec. 36 seem to support the opinion that this area is not likely to produce large amounts of oil.

SAND CONDITIONS.

Little is known about the effect of sand conditions in Osage County, as no detailed work on the sands has been attempted. Undoubtedly changing sand conditions may affect favorably or unfavorably the oil production in any region and may nullify the effects of otherwise favorable structure or cause the accumulation of oil in areas where its presence would not be indicated by the structure. The tightening of the sands down the dip from places of favorable structure might prevent the migration of oil into such places, and on the other hand the tightening of the sands up the dip from a porous sand might cause the accumulation of oil in a monocline or even on the flanks of a syncline.

PRODUCTION.

The only oil-producing territory in the area here discussed is in secs. 5 and 6, T. 22 N., R. 11 E., on the southeastern flank of the Fox dome, and in sec. 20 of the same township, where there is one well. In this part of the Fox dome the initial production is small, and the present average production is about 1 barrel a day. These wells are unfavorably located, and their production does not indicate what may be expected from wells in more favorable structural positions. The one well in sec. 20 is said to be producing 25 barrels a day.

Some idea of the possibilities of obtaining oil in this area may be gained from the conditions in Tps. 20 and 21 N., R. 12 E., to the southeast, where development has been more thorough. Here the initial production ranges from a few barrels to 150 barrels a day and the average is between 40 and 50 barrels. Drilling began in 1908 and reached its climax in 1914. By the end of 1917 the average production per well had dropped to about 10 barrels a day, but this rate seems to be rather well maintained.

The Bartlesville sand is yielding most of the oil produced in the eastern part of Osage County, and it seems probable that this sand will prove to be the most productive here also. In the southeastern part of T. 22 N., R. 10 E., oil is derived from the Cleveland sand, 750 to 800 feet below the Avant limestone, and this bed may yield some oil in Tps. 21 and 22 N., R. 11 E. A few wells in sec. 3, T. 21 N., R. 12 E., are reported to be producing oil from the "Mississippi lime," and that bed should be thoroughly tested in this region at a locality favorable for oil. Drilling has usually been continued to the "Mississippi lime" only where the beds at higher horizons proved to be dry, and so there have been few adequate tests of that formation.

T. 24 N., R. 9 E.

By K. C. HEALD, C. F. BOWEN, and others.

INTRODUCTION.

The field work in T. 24 N., R. 9 E., was done by K. C. Heald, C. F. Bowen, D. D. Condit, and W. B. Emery. Their responsibility for the mapping of the entire township is indicated by the order in which their names are given. They were effectively assisted by W. L. Miller and J. M. Vetter, whose work with the plane table added materially to the detailed accuracy of the results.

The positions of the outcrops of the beds and the elevations on which the structure contouring is based were determined by plane table and telescopic alidade, with the exception of a few points which were located by compass bearing and pacing traverse, and whose elevations were determined by barometric observations.

ROCKS EXPOSED.

GENERAL FEATURES.

The rocks exposed in T. 24 N., R. 9 E., include sandstones, shales, and limestones of upper Pennsylvanian age. (See fig. 31.) The sandstones are by far the most noticeable rocks in the township because of their prominent outcrops, most of which are emphasized by a thick growth of oak and hickory, in contrast to the unforested condition of the adjoining areas where shales crop out, but the aggregate thickness of the sandstone is in fact less than that of the shales. The exact thickness of either sandstones or shales can not be accurately determined, because the basal sandstone beds are in most places slumped in such a manner that the exact contact with the shale can not be seen. In many places benches of shale between sandstone ledges are so concealed under blocks of sandstone that the presence of shale can be proved only by pulling up large fragments of sandstone and digging into the underlying soil. Limestones are conspicuous in only two localities in the township—near the north line of sec. 8 and in the extreme northeast corner of sec. 29. At these two places the lower beds of the Pawhuska limestone form outliers which are particularly prominent because they cap hills that stand up above the general level of the surrounding ridge. The Oread limestone, which is the only other definite limestone bed in T. 24 N., R. 9 E., is extremely inconspicuous. A few of the beds that were particularly helpful in determining the geologic structure are described in some detail below.

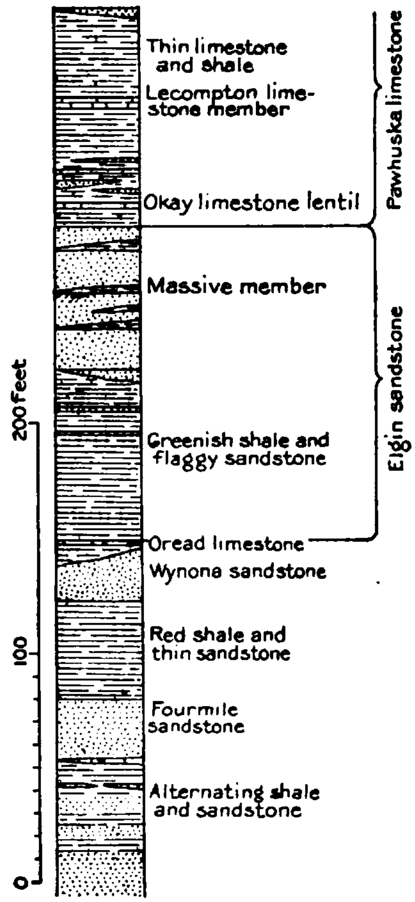


FIGURE 31.—Section of rocks exposed in T. 24 N., R. 9 E.

KEY BEDS.

Elgin sandstone.—The Elgin sandstone, which immediately underlies the Pawhuska limestone, is about 135 feet thick in T. 24 N., R. 9 E. The upper half of the formation is massive sandstone, with thin lentils of shale; in the lower half heavy beds of green shale alternate with thin, flaggy sandstone. Except in a few places, the flaggy sandstone in the lower part of the formation can be traced only for short distances, and it is extremely difficult to distinguish between the different beds—conditions which make correlation across concealed areas very uncertain. For this reason most of the structure in that part of the township where the Elgin sandstone is the surface formation was determined by work on the massive sandstone in the upper part of the formation. Where lentils of shale are present between members of this massive sandstone there are prominent ledges which may be traced with certainty, but the shale lentils are only local, and many of the sandstone ledges terminate abruptly, merging into thicker beds of unbroken sandstone. The most persistent of the shale lentils lies about 45 feet below the top of the Elgin sandstone. As much mapping as possible was done on the top of the underlying sandstone ledge. The shale above it can usually be seen only in freshly cut stream channels or by digging some distance into the soil above the top of this heavy lower ledge, but its presence is indicated by a persistent bench that may be followed with considerable certainty. The shale ranges in color from a bright red to an olive-green, with small crimson blotches, and in thickness from a few inches to 5 feet. The sandstone below the shale is in most places coarser in texture than the higher beds of the Elgin sandstone, and its grains are less uniform in size. Shale inclusions are not uncommon, particularly near the very base of the bed, which in places presents a ragged appearance, due to the weathering out of these inclusions. However, similar ragged surfaces have been observed in some of the overlying beds, so that this characteristic is not of great value as an aid to correlation.

Below this basal sandstone is a thick bed of yellowish to olive-drab shale, which by its creeping permits large blocks of the overlying sandstone to break off and slump down the hill. Accordingly the outcrop of this basal massive ledge is much more likely to be marked by large tilted and slumped blocks than those of any of the overlying sandstone members, which are underlain by comparatively thin lentils of shale.

The structure mapping over the western third of T. 24 N., R. 9 E., is based largely on work done on the Elgin sandstone. Good localities for studying are the central part of sec. 7, the NE. ¼ sec. 8, and the south-central part of sec. 17.

Oread limestone.—The Oread limestone, which in this township is about 135 feet below the top of the Elgin sandstone, crops out in only a few localities, but its failure to appear is probably due more to the thinness, solubility, and general inconspicuous character of the bed than to its actual absence. Such outcrops as were observed show it to be a hard, compact crystalline limestone, orange-red on the weathered surface and gray on the fresh surface, with few fossils. Associated with it are dark-gray shales, which in many localities are very fossiliferous. The fossils weather out, and the horizon of the Oread may be followed by finding them associated with small limestone nubbins, even where no outcrops are visible. In localities where even these markers are absent the general horizon of the bed is marked by tiny nodules of chalk-white lime which have weathered out of the shale. These nodules are probably of secondary growth, and similar ones have been observed at other horizons where there are limy shales, but near the Oread limestone they appear to be limited to the shales immediately adjacent to the limestone.

The horizon of the Oread limestone was traced through the township from north to south. (See Pl. XXXII.) A good locality for examining it is in the west-central part of sec. 27, where it has been uncovered in a pipe-line trench.

Wynona sandstone.—The Wynona sandstone, which lies from 2 to 15 feet below the Oread limestone, is a massive bed 15 to 25 feet thick, similar in characteristics to other sandstones in the Pawhuska quadrangle. In the south-central part of this township the sandstone loses its massive character and is a thin, flaggy bed which may locally grade into a massive sandstone quite like that in the northern part of the township.

Above the Wynona sandstone is a bed of red shale 2 to 10 feet thick which terminates abruptly below the Oread limestone and is succeeded by the dark fossiliferous shales that accompany that bed. Below the Wynona sandstone there is a thick series of alternating red shales and sandstones.

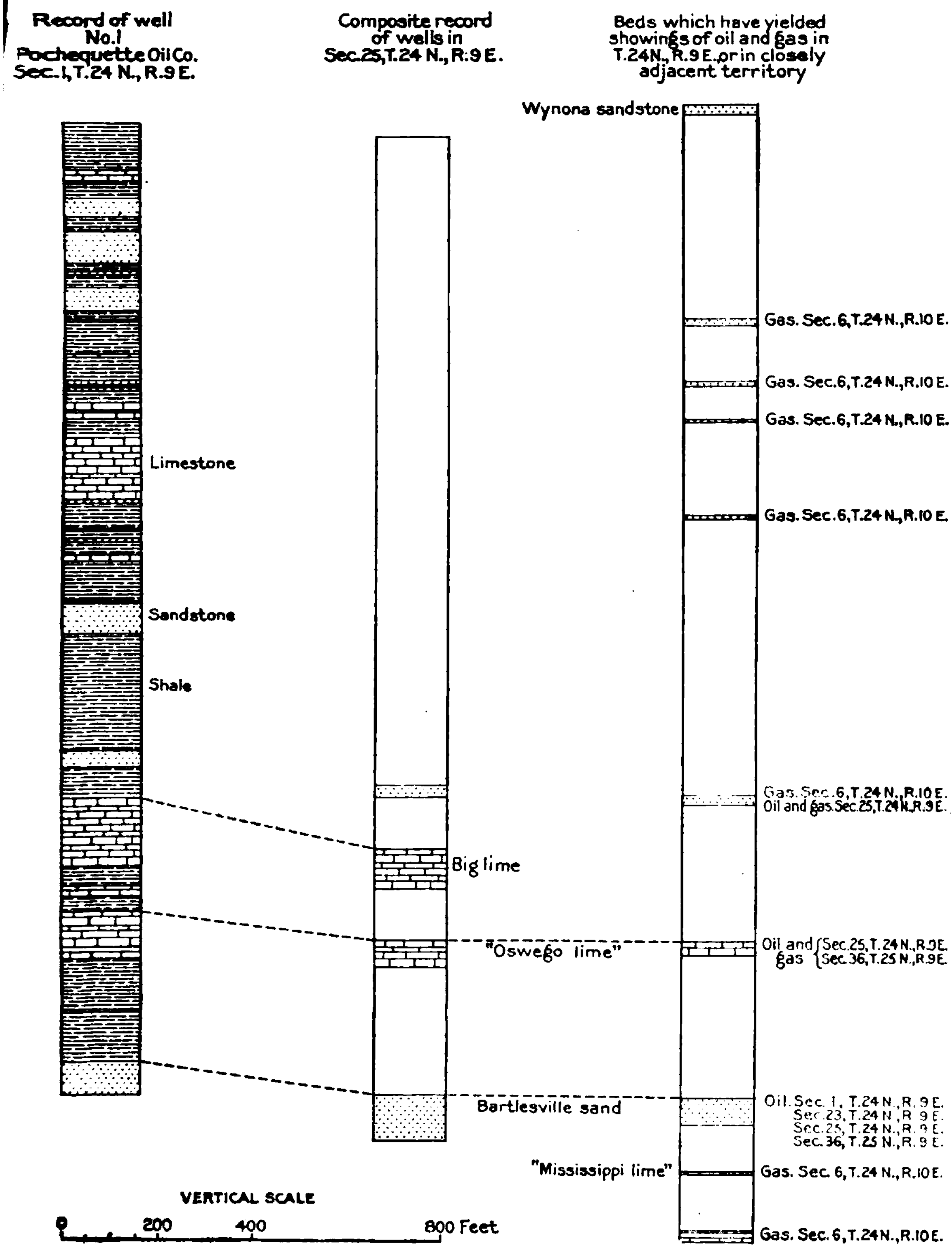
The Wynona sandstone covers the eastern half of the township, and the structure over this eastern half is determined from elevations either on the Wynona itself or on one of the underlying beds whose distance below the datum plane was determined by its relation to the Wynona sandstone. A good locality for studying this sandstone is just north of Wynona and in the northern outskirts of the town.

The outcrop line shown on the map (Pl. XXXII) does not represent the very top of the bed but is drawn so that it will include about 5 feet of the sandstone.

PENNSYLVANIAN ROCKS NOT EXPOSED.

The unexposed rocks above the "Mississippi lime" in T. 24 N., R. 9 E., are of the same general type as those which crop out. Sandstone and shale make up about 70 per cent of the total above what is known to the drillers as the Big lime (probably the Pawnee limestone of Kansas). Below that bed there is much more limestone and correspondingly less sandstone.

Either oil or gas has been reported from nine distinct beds in wells that have been drilled in T. 24 N., R. 9 E. (Pl. XXXIII). The uppermost of these beds have yielded only showings of gas, which will not be sufficient in volume to justify their utilization; but five deeper beds, three in the Pennsylvanian and two probably in the Mississippian, have yielded commercial amounts of oil or gas. The highest of these beds is about 1,470 feet below the top of the Wynona sandstone, and may perhaps be correlated with what is called the Peru sand in the fields northeast of T. 24 N., R. 9 E. The next lower productive bed is the Fort Scott ("Oswego") limestone, about 1,780 feet below the Wynona sandstone. In some wells just outside of T. 24 N., R. 9 E., oil and gas is reported to come from the limestone itself; in others it comes from a thin sandstone just above the Fort Scott. The third and most productive bed is the Bartlesville sand. Not enough work has been done to determine whether or not this is actually the same sandstone as the one that produces oil in the neighborhood of Bartlesville, but it is at approximately the same horizon. The most productive of the wells, both in T. 24 N., R. 9 E., and in the adjoining townships, obtain their oil from beds that occupy the general horizon of the Bartlesville sand. This sandstone is believed to



WELL RECORDS SHOWING DRILLERS' INTERPRETATIONS OF BEDS UNDERLYING T. 24 N., R. 9 E., AND GENERALIZED SECTION SHOWING APPROXIMATE POSITION OF OIL AND GAS BEARING BEDS.

be from 60 to 80 feet thick near the eastern border of the township and to grow thinner toward the west, so that near the western border it probably has a thickness of 15 feet or less. The two deepest of the producing beds are parts of the "Mississippi lime." They are comparatively thin beds of coarse limestone, and in wells drilled just east of the northeast corner of T. 24 N., R. 9 E., they contain large volumes of gas. This gas is reported to contain a considerable percentage of heavy hydrocarbons, which indicate the probability that these beds also contain oil. The lower of these two beds is about 2,400 feet below the Wynona sandstone.

STRUCTURE.

GENERAL FEATURES.

The rocks in T. 24 N., R. 9 E., are so extensively folded and individual anticlines and synclines are so irregular in outline that a casual examination of the map (Pl. XXXII) may not reveal any

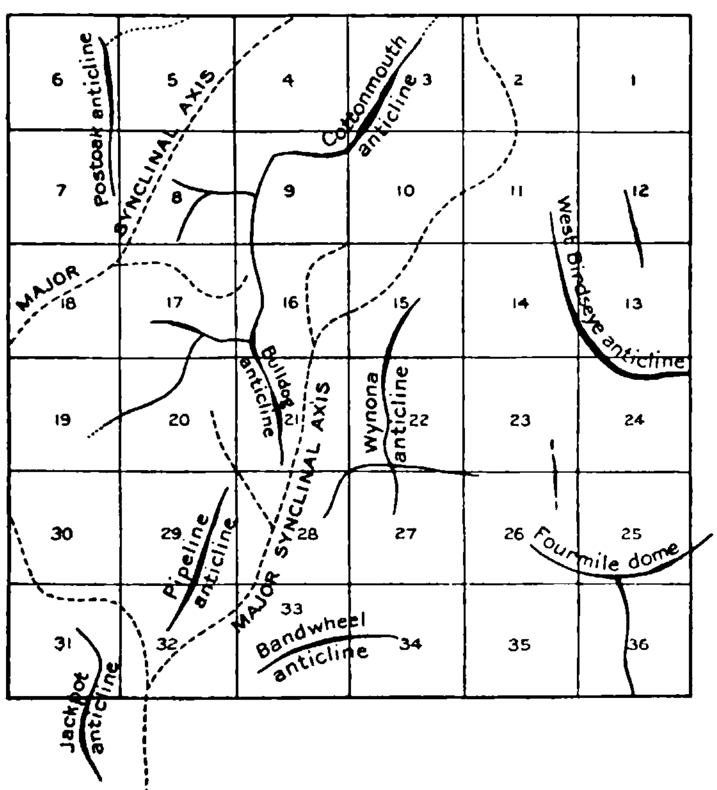


FIGURE 32.—Diagram showing positions of anticlinal and major synclinal axes in T. 24 N., R. 9 E.

particular system of deformation. Careful examination, however, shows that there is a very definite arrangement both of folds and faults. A major synclinal axis which marks the bottom of the structural trough passes through the next township to the south about a quarter of a mile east of the southwest corner of sec. 32 and goes northward through secs. 28, 21, 16, 15, 10, 11, and 2, whence it crosses the line into T. 25 N., R. 9 E. On both sides of this syncline the rocks are buckled into anticlinal folds of irregular outline and dimension. The axes of the individual folds trend in various directions (see fig. 32), but the system taken as a whole is roughly parallel to the course of the major syncline. On the west side of the major syncline there is a series of small roughly parallel faults which cut the east flank and crests of several of the anticlines (Pl. XXXII).

In the western part of T. 24 N., R. 9 E., there is a second synclinal axis. This axis branches into the SW. ¼ sec. 32 from the one mentioned above and trends northwestward until it passes out of the township near the northwest corner of sec. 30. It reenters the township near the southwest corner of sec. 18, trends northeastward through secs. 18, 8, 5, and 4, and passes into T. 25 N., R. 9 E., a little west of the north quarter corner of sec. 4 (fig. 32). Between this axis and that of other major synclines is the line of faulted anticlinal folds mentioned in the preceding paragraph. West of it also there are some anticlinal folds which, however, are not nearly so pronounced as those on the east.

These upfolds and downfolds are developed in a tilted surface that slopes to the west at an average rate of 25 feet to the mile, so that in spite of minor anticlinal structure which may bring the beds in any part of the township toward the surface, any definite bed will be about 150 feet nearer sea level at the west line of the township than it is at the east line.

AREAS STRUCTURALLY SUITED TO INDUCE THE ACCUMULATION OF OIL.

Areas underlain by beds having anticlinal structure are by far the best localities in which to prospect for oil or gas, but experience in the Osage Reservation has shown that these minerals are not restricted to such areas. Structural terraces, in which flat-lying rocks lie adjacent to steeply dipping rocks, have been productive in some regions; terraces adjacent to faults that displace the oil-bearing beds may be underlain by oil pools; and in regions of pronounced deformation extensive pools of oil and gas have been found underlying synclines. However, the importance of anticlinal structure should be emphasized, for by far the greatest part of the oil produced in the Osage Reservation comes from pools that underlie such folds. It has also been established that the more pronounced the anticline and the greater its closure the greater is the likelihood of its yielding a large quantity of oil.

ANTICLINES.

COTTONMOUTH ANTICLINE.

The axis of the Cottonmouth anticline traverses sec. 3 from northeast to south, crosses the extreme northwest corner of sec.

10, and runs west to a point near the center of the NW. ¼ sec. 9, where it swings south and divides, one branch going west into sec. 8, the other south into sec. 16, where it joins the northern extension of the Bulldog anticline. This is a well-developed fold with a closure of at least 40 feet. The rocks slope in all directions from the extreme northwest corner of sec. 10. The dips to the northeast and southwest along the axis are gentle but none the less definite; those to the northwest and southeast are abrupt. The anticline is cut by four roughly parallel faults which strike about N. 30° W. and range in maximum throw from 10 to 35 feet and in length from a quarter of a mile to a mile. Two of these faults dislocate only the rocks on the east side of the fold; the other two cut across the axis. Only one of them is large enough or in a position to have any probable effect on the oil-bearing possibilities of the anticline. This one cuts squarely across the axis of the fold just southwest of the northeast corner of sec. 9 and drops the strata to the southwest a maximum distance of about 35 feet without obliterating the anticlinal arch. It extends well down to the synclines on the northwest and southeast flanks of the anticline but dies out without reaching their axes. If this fault is as extensive in the oil-bearing strata as it is in the surface strata, it has probably a decided effect on the shape and location of any oil pool that may have formed below the axis of the anticline in the sands above the Bartlesville sand. Its effect is believed, however, to be limited to these shallow sands, because they are comparatively thin and a break of 35 feet could seal their entire thickness, whereas the Bartlesville, if present, is probably more than 35 feet thick and so could not be effectively broken by the fault. (See fig. 33.)

The Cottonmouth anticline is about 2 miles from the nearest oil field, which lies in secs. 25, 26, 35, and 36, T. 25 N., R. 9 E.; it is but little farther from a field in sec. 6, T. 24 N., R. 10 E., and there are two wells in sec. 1, T. 24 N., R. 9 E., which lie between these two fields. In these fields gas was encountered in five distinct sands above the Fort Scott ("Oswego") limestone, but no effort has been made to utilize this shallow gas. The Fort Scott limestone yields both oil and gas in the field in T. 25 N., R. 9 E., and gas in sec. 6, T. 24 N., R. 10 E. The highest initial daily production of oil from this bed was about 20 barrels. The Bartlesville sand, about 300 feet below the Fort Scott limestone, yields most of the oil in both the fields mentioned above. In sec. 6, T. 24 N., R. 10 E., some wells have had an initial production as high as 600 barrels; in the other field the best initial production was about 1,000 barrels. Below the Bartlesville there are at least two limestones which are known to be gas bearing and which probably also contain oil but whose possibilities have not been determined. However, the deep gas-bearing beds are believed to be comparatively thin, so it is not to be expected that they will rival the Bartlesville sand in total oil yield, although they may yield large amounts of oil for short periods.

The Cottonmouth anticline is believed to be splendid prospective oil and gas territory; it has ample gathering ground on its flanks and in the adjacent syncline to furnish a large amount of oil and gas; it has a large enough closure to make it an effective trap for these minerals; such faults as cut it do not injure its oil-retaining capabilities; and sands which presumably underlie it are known to contain oil and gas a short distance away.

Good locations for wells to prove this fold are the center of the SW. ¼ SW. ¼ sec. 3; the center of the SE. ¼ NE. ¼ sec. 9, and the center of the NW. ¼ sec. 9. Wells drilled at these locations should encounter the Fort Scott ("Oswego") limestone at a depth of about 1,800 feet, the Bartlesville sand at about 2,120 feet, and the deep gas-bearing beds in the "Mississippi lime" at about 2,420 feet. Test holes should be drilled to about 2,500 feet unless oil or gas is found in paying quantities at less depth.

POSTOAK ANTICLINE.

The Postoak anticline is a small, inconspicuous fold in the northwest corner of T. 24 N., R. 9 E. Its major axis, which is a little more than a mile long, extends from a point a little west of the east quarter corner of sec. 6 to a point northwest of the east quarter corner sec. 7, where it is lost in a saddle that separates the Postoak anticline from the Wooster anticline (fig. 32). The highest part of the fold is about 900 feet west of the east quarter corner of sec. 6, and the area surrounded by the lowest closed contour includes the central part of the E. ½ sec. 6 and of the W. ½ sec. 5, embracing about 160 acres in all. The closure is about 30 feet. (See Pl. XXXII.)

Almost all the elevations by which the shape and size of this anticline were determined were taken on members of the Elgin sandstone, and because of the difficulty of tracing these beds accurately over the timber and soil covered slopes on which this anticline lies, it is entirely probable that the shape and size of the fold may not be exactly as shown on the map. However, the work was done with care and in detail, and it is believed that the portrayal of the structure is correct except in very minor points.

Not enough data are available to justify a definite forecast of the possibilities of this anticline. Such wells as have been drilled near by have been so located that their failure to yield commercial quantities of oil has no bearing on the possibilities of the anticline. Furthermore, no records of these wells are available, and it is not known whether or not they were drilled deep enough to encounter the beds that yield oil and gas in the nearest fields. Only one of these wells was seen by the writers; it is in the northwest corner of sec. 8, in the syncline southeast of the Postoak anticline. At the site there were the remains of an old demolished rig but no boiler foundation, clinker pile, sludge pit, or other definite evidence that drilling had actually been done.

The oil fields nearest the Postoak anticline are those in the southeast corner of T. 25 N., R. 9 E., and the northeast corner of T. 24 N., R. 10 E., which are mentioned in the foregoing description of the Cottonmouth anticline. In sec. 33, T. 25 N., R. 8 E., 4 miles west of the Postoak anticlines, a well that was drilled since the completion of the field work on which this report is based found large volumes of gas in three sands above the Big lime and enough oil at the horizon of the Fort Scott limestone to make a 5-barrel well. Farther south, in sec. 15, T. 24 N., R. 8 E., a well drilled to the Fort Scott limestone found several gas-bearing sands and one sand that yielded a small showing of oil. The greatest yield in this well comes from the Big lime, although the Fort Scott limestone is also fairly productive. As the beds at the general horizon of the Fort Scott limestone have been proved to be productive east, west, and southwest of the Postoak anticline, it is a fair conclusion that they probably contain oil or gas in this anticline also. The productivity of the deeper beds is more uncertain. The record of the dry hole that was drilled to the "Mississippi lime" in sec. 18, T. 25 N., R. 8 E., does not report any sands between the Fort Scott limestone and the "Mississippi lime," and it is entirely possible that the sand is also lacking in the northwest corner of T. 24 N., R. 9 E. If so it will probably be profitable to sink wells into the "Mississippi lime" to tap the beds which yielded gas in the deep wells in sec. 6, T. 24 N., R. 10 E., and which carry gas and oil elsewhere in Osage County. In spite of the small size of the Postoak anticline its prospects are believed to be very good. It has an ample gathering ground from which oil and gas may migrate up smoothly dipping beds to accumulate under the anticlinal fold. The reversal of the dip is sufficient to make an effective trap to stop the movement of the oil and gas; the fold is in a general zone of pronounced deformation, such as has yielded large volumes of oil and gas elsewhere in the Osage Reservation; and oil sands which have been reached in wells both east and west of the fold are probably also present at this locality. A good place for a test well is about the middle of the north line of the SE. ¼ sec. 6. At this point the Fort Scott limestone probably lies between 1,900 and 1,950 feet below the surface, the Bartlesville sand, if it is present, at about 2,250 feet, and the "Mississippi lime" at about 2,400 feet. The test should be carried to a depth of 2,700 feet unless a good yield is obtained at shallower depths, and even though oil in quantity is found in one of the higher sands, a test should ultimately be sunk to determine the contents of the lower beds in the "Mississippi lime."

WEST BIRDSEYE ANTICLINE.

The West Birdseye anticline lies in the eastern part of T. 24 N., R. 9 E., and joins the East Birdseye anticline near the west line of T. 24 N., R. 10 E. Its axis follows a curving line from a point a little south of the northeast corner of sec. 24 through the southwest corner of sec. 13 and the northeast corner of sec. 14 into the southeast corner of sec. 11. (See fig. 32.) The closure is only about 30 feet, but the dips to the north, west, and south are so pronounced and the opening to the east is so narrow that a large pool of oil and gas should have accumulated in the fold. The area included within the lowest closed contour is less than 640 acres, but the structure has probably influenced the accumulation of oil and gas over a much larger area.

At the time the field work for this report was completed there were two wells on the West Birdseye anticline. One of these, in the SW. ¼ sec. 13, produces gas from what is believed to be the Bartlesville sand; the other, in the NE. ¼ sec. 23, produces oil from a sand which is also called the Bartlesville but which lies beneath the sand in the gas well. Since the completion of the field work a second well has been completed in the northeast corner of sec. 23. This well, which is reported to have had an initial yield of 150 barrels a day, is the best of those that have been drilled on the anticline to date.

Not enough drilling has been done to determine to what extent the entire anticline contains oil and gas. However, the relation of the oil wells to the gas well and the conditions known to exist in other anticlines in the Osage Reservation indicate that the crest of the fold may be occupied exclusively by gas and that the flanks on all sides may yield oil. The general experience in the Osage Reservation is that the west flanks of anticlines are more likely to be oil-bearing territory than the other flanks, but in this particular region there is reason to believe that the generalization does not hold. On the Saucy Calf anticline, 2 miles north of the West Birdseye anticline, the east flank yields oil; the same is true of the Thirty-six anticline, in sec. 36, T. 24 N., R. 8 E., and of the Fourmile dome, just south of the West Birdseye anticline. Accordingly, in the absence of the positive evidence which drilling will afford, the east flank of the West Birdseye anticline is considered very favorable territory. The evidence of the wells that have been drilled on this fold and in fields to the north and south shows that the principal oil-bearing bed below this fold will probably be at the general horizon of the Bartlesville sand. However, it is probable that somewhere on the anticline beds above the Bartlesville will also be productive and that exploration of the "Mississippi lime" below the Bartlesville sand will reveal oil or gas bearing beds.

That extensive and remunerative oil fields are certain to be developed on the West Birdseye anticline is indicated by the oil wells already drilled, by the sharpness of the anticlinal fold, and by the ample gathering ground on the north, west, and south from which the oil may have moved to collect under the anticline. Good locations for further testing are the center of the SE. ¼ NE. ¼ sec. 14 and the center of the SE. ¼ NW. ¼ sec. 24. The wells should be drilled at least 300 feet below the top of the "Mississippi lime" unless oil is obtained at a shallower depth.

WYNONA ANTICLINE.

The Wynona anticline is a terrace-like fold that might be considered a part of the West Birdseye anticline, as there is no continuous syncline between the two folds, but it is sufficiently pronounced to deserve a separate description. The principal axis of the Wynona anticline follows a slightly sinuous course with a general northerly trend, passing from the north-central part of sec. 27 to a point a little east of the center of sec. 15. Crossing this main axis almost at right angles are two minor axes, the northern one near the south line of sec. 16 and the other near the south line of sec. 22. At each end of the main axis there is a domelike swell whose center coincides with the point at which the main axis is intersected by the minor axis, and between these domes there is a broad saddle. The crown of the north dome is just northwest of the south quarter corner of sec. 15. The closure of this dome is but a little more than 10 feet, and the area surrounded by the lowest closed contour is only about 160 acres, but it seems probable that the doming has exerted an influence over double this acreage. The crown of the south dome, which is even smaller than the other, is in the southeast corner of the SW. ¼ sec. 22. This dome also has a closure of a little more than 10 feet, but the area inclosed by the lowest closed contour is only about 10 acres. However, there is a pronounced anticlinal arching of the beds both to the east and to the west, and this territory appears almost as promising as that on the north dome. Just east of the lowest closed contour on the south dome is a small fault, but its throw is so small that it has probably had no serious influence on any oil pool which may have formed beneath the fold.

The single well which has been drilled on the Wynona anticline is on the flank of the north dome, fairly well down toward a syncline which borders the dome on the north. This well was unsuccessful, but no record of it could be obtained, and therefore its significance is not known. If it reached the Bartlesville sand it has a material bearing on the potential value of the anticline, but if, like many of the tests which were drilled in the Osage country years ago, it was abandoned before it reached the Bartlesville sand it signifies little. In the absence of definite knowledge concerning its depth little weight should be attached to it as evidence condemning territory that is structurally favorable for the accumulation of oil and gas.

To judge from the conditions in the producing wells on the West Birdseye anticline, a mile and a half to the east, the formation which is most likely to yield oil under the Wynona anticline is the Bartlesville sand, although it is not impossible that some one of the shallower beds may also prove productive. If drilling is carried below the Bartlesville sand the "Mississippi lime" will probably be found to contain gas and perhaps oil. The "Mississippi lime" is known to be gas bearing under the North Cochahee dome, 4 miles to the northeast, and both oil and gas have been produced from it elsewhere in the Osage Reservation.

The prospects of production from the Wynona anticline appear good. There is a very well defined closure, particularly in the dome at the north end of the fold, and a reasonably large gathering ground to the north, west, and south. Wells drilled a short distance to the east which have found oil in quantity and producing wells a few miles to the southwest which obtain oil from beds at the same general horizon make it seem probable that there is a continuous sand between the two fields, and such a sand would necessarily underlie the Wynona anticline. Good locations for test wells are the center of the SW. ¼ SW. ¼ sec. 15 and the center of the SE. ¼ SW. ¼ sec. 22. Wells drilled at these locations should reach the Fort Scott ("Oswego") limestone at a depth of about 1,800 feet, the Bartlesville between 2,100 and 2,200 feet, and the lower productive strata of the "Mississippi lime" at about 2,400 feet. To be adequate a test hole should be drilled to a depth of at least 2,500 feet.

FOURMILE DOME.

The Fourmile dome lies in the southeast corner of T. 24 N., R. 9 E. Its axis passes in a crescentic line from a point near the center of sec. 26 across sec. 25 near its south line and into sec. 30, T. 24 N., R. 10 E. Near the middle of the south line of sec. 25 a minor axis branches off and runs almost due south across sec. 36 and into T. 23 N., R. 9 E. The closure in this fold is about 20 feet, but the beds on its flanks dip so gently that it has more the appearance of a terrace and it is quite unlike most of the more productive anticlines in the Osage Reservation, which have steeply pitching flanks.

It is known that at least one oil-bearing sand underlies this fold, for a small field has been developed on the east flank of the dome in sec. 25, T. 24 N., R. 9 E., and sec. 30, T. 24 N., R. 10 E. The oil in this field comes from the Bartlesville sand, which is reported to be about 70 feet thick, and wells with an initial production of 50 barrels a day have been completed, although the average initial production was considerably lower. Much larger wells might be expected were it not for the position of the field far down on the east flank of the anticline—indeed, some of the wells are in the shallow syncline that separates the Fourmile dome from the West Birdseye anticline. The fact that oil in commercial quantities is obtained from wells drilled in the syncline probably indicates either that the sand conditions are unusually favorable at this locality or that the underground structure is not similar to that at the surface. A pool might much more logically be expected to the south and west of the existing field, higher on the flanks of the anticline, and there is every reason to hope that exploration of parts of the dome which are structurally more favorable than the existing field will result in the discovery of larger accumulations of oil.

The anticline should be developed by the extension of the existing field toward the south and west. However, even should attempts to expand this field result in failure other portions of the dome should be tested. The structure is sufficiently favorable to justify thorough prospecting, regardless of any barren patches which may be demonstrated to underlie portions of the fold. It is known that some barren patches exist under almost every productive anticline in the Osage Reservation. Good locations for tests are the center of the SW. ¼ SE. ¼ sec. 25, the extreme southeast corner of sec. 25, the center of the SE. ¼ SE. ¼ sec. 26, and the center of sec. 36. The Bartlesville sand should be found less than 2,100 feet below the surface at all these locations. If oil or gas in commercial quantity is not found in the Bartlesville sand the wells should be deepened to the "Mississippi lime" and should not be abandoned at a depth of less than 2,400 feet.

The Fourmile dome is in a zone of marked deformation, and there is a strong possibility that some folding of the deep-lying beds took place before the rocks now exposed at the surface were deposited. If this was so the anticlinal structure is almost certainly more pronounced in the "Mississippi lime" than in the Bartlesville sand, and with this possibility in view wells should ultimately be bored deep into the "Mississippi lime," even though the Bartlesville sand proves to contain great volumes of oil.

BANDWHEEL ANTICLINE.

The Bandwheel anticline is just north of the south line of T. 24 N., R. 9 E., in secs. 33 and 34. Its curving axis is shaped like a bow with one end to the south, in the SW. ¼ sec. 33, and the other near the center of sec. 34. (See fig. 32.) It is a low, inconspicuous fold with a closure of only a little more than 10 feet. The flanks of the anticline incline gently to the north, east, and south and very steeply to the west. South of the crown of the Bandwheel anticline the rocks dip southwestward for only about half a mile and then the dip is reversed and they mount to the summit of another anticlinal fold which appears to be somewhat larger than the Bandwheel anticline. Only a part of this second fold was mapped by the writers, but enough of it was seen to justify the statement that it is a true anticline and is accordingly prospective oil-bearing territory. It is introduced into this discussion of the Bandwheel anticline because its presence indicates that the structural saddle which limits the Bandwheel anticline on the south should probably not be considered as unfavorable for oil accumulation as the other marginal synclines.

No oil wells have been drilled nearer to the Bandwheel anticline than those in sec. 36, T. 24 N., R. 8 E., some 2½ miles to the west. These wells, which are on a large anticlinal fold known as the Thirty-six anticline, obtain oil and gas from five beds, all above the "Mississippi lime." The highest of these beds, the Layton sand, lies 500 to 600 feet above the Big lime and is reported to yield only small volumes of oil and gas. The Big lime itself has contributed a little oil and gas to the total production, but like the Layton sand it is relatively unimportant in the field in sec. 36. A little below the Big lime is the Peru sand, about 25 feet thick, which in some of the wells mentioned above yields oil and gas. The Fort Scott ("Oswego") limestone is about 200 feet lower, and just above it there is a thin sand from which some of the wells obtain most of their oil. About 300 feet below the Fort Scott limestone is a sand about 15 feet thick which is known as the Bartlesville, although it can not be certainly correlated with the Bartlesville sand that yields oil in other parts of the Osage Reservation. This sand contains oil but is very "spotted"—that is, it is not uniformly oil bearing but may yield abundantly in one well and practically nothing in other wells near by.

A single well has been drilled on the Bandwheel anticline, but as no record of the formations encountered is available it is not known whether any of the above-mentioned beds were recognized in this well or, indeed, if it was drilled deep enough to reach even the shallowest of them, although the accumulation of sludge in the old sludge pit indicates that a considerable depth was reached. A well that was drilled a short distance to the east of the Bandwheel anticline reached the "Mississippi lime" at a depth of 2,178 feet. No detailed record of this well could be obtained, but it was learned that the well passed through a sand about 15 feet thick a few feet above the "Mississippi lime," and it is likely that this sand is the Bartlesville.

It seems probable that oil will be found below the Bandwheel anticline in one of the shallow sands that are productive in sec. 36, T. 24 N., R. 8 E., in the Bartlesville sand, or in the "Mississippi lime." However, it should not be expected that any oil pool will be found to lie uniformly below the entire area covered by this fold; on the contrary, parts of the anticline will probably prove to be barren of commercial quantities of oil and gas. The failure of a single test, even though it may be in a very favorable structural location, should not be considered evidence that will condemn the entire anticline, and a number of dry holes far down on the flank of the anticline are to be expected. Accordingly the failure of the one well which has been drilled on this fold is not particularly discouraging, for it was not favorably located with respect to structure, nor is it known that it was drilled deep enough to constitute an adequate test. Good locations for further testing are the center of the NW. ¼ SE. ¼ sec. 33 and the center of the SW. ¼ sec. 33. In either of these locations the Bartlesville sand should lie between 2,100 and 2,200 feet below the surface and the other possible oil-bearing beds above the "Mississippi lime" should bear approximately the same relation to it as they do in the wells in sec. 36, T. 24 N., R. 8 E.

JACKPOT ANTICLINE.

The Jackpot anticline is a small fold whose curving axis extends from a point a little east of the center of sec. 21, T. 24 N., R. 9 E., to a point a little southeast of the center of sec. 6, T. 23 N., R. 9 E. (See fig. 32.) Only the crest and north end of this anticline were mapped, and it is not possible to state definitely just how large it is or what is its closure. However, it is believed to have a closure of 15 to 20 feet, and the area which is structurally favorable for oil accumulation is probably less than a square mile, covering part of the SW. ¼ sec. 31 and the E. ½ sec. 6.

The crest of this anticline is cut by a fault, which, however, is not large enough to have had any appreciable influence on the oil possibilities of the fold. So far as can be learned similar small faults in producing fields in the Osage Reservation have not affected either favorably or adversely the territory immediately adjacent to them.

The nearest producing field is in sec. 36, T. 24 N., R. 8 E., and the sands which bear oil there may reasonably be expected to be found beneath the Jackpot anticline, although it can not be stated positively either that they are present or that if present they contain oil. The general relations of these sands have been discussed in the description of the Bandwheel anticline (p. 206). So far as has been ascertained no wells have been drilled either on or immediately adjacent to the Jackpot anticline. A well drilled in the NW. ¼ sec. 6, T. 23 N., R. 9 E., would be squarely on the crest of the fold and if drilled deep enough should furnish a very fair test of it. The Fort Scott limestone probably lies about 1,700 feet below the surface, and the Bartlesville sand should be 300 feet lower.

PIPELINE ANTICLINE.

The Pipeline anticline, in the southwestern part of T. 24 N., R. 9 E., is a long, relatively narrow fold with strong dips to the north, west, and south but a very gentle dip to the east. The closure is

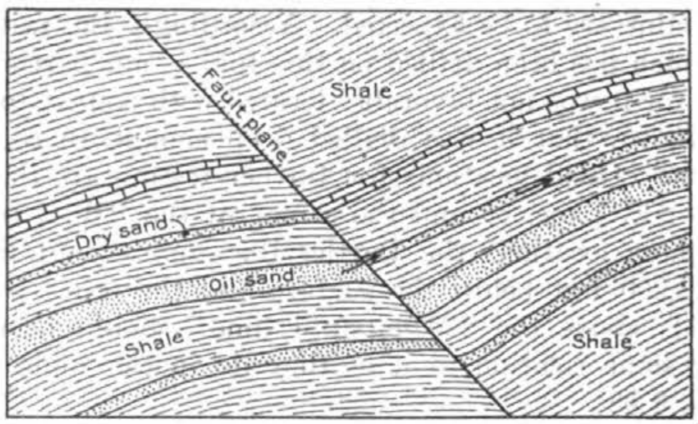


FIGURE 33.—Sketch showing conditions that might permit the escape of oil from a faulted anticline, such as the Pipeline anticline.

about 15 feet, and the area included within the lowest closed contour is considerably less than half a square mile. The axis runs nearly straight from a point a little west of the center of sec. 32 almost to the northeast corner of sec. 29. At its north end it terminates abruptly against a fault which has dropped the beds to the northeast a maximum amount of about 60 feet. Were it not for this fault the Pipeline anticline would probably join the Bulldog anticline, to the east. (See Pl. XXXII and fig. 32.) It is possible that the fault may have affected to some extent the ability of the Pipeline anticline to retain oil. If the beds are faulted in such a manner that a porous sand east of the fault is in contact with an oil-bearing bed west of the fault, a ready avenue of escape for the oil was provided and it may have migrated up the slope to the Bulldog anticline. It is not believed that such a condition exists under the Pipeline anticline, but it must be recognized as a possibility. The possible conditions are shown graphically in figure 33.

It does not appear probable that the Pipeline anticline contains any very great amount of either oil or gas, for this fold does not compare favorably either in size or in shape with the more productive anticlines in the Osage Reservation. However, it does seem probable that wells of moderate productivity will be obtained here. This conclusion is supported by the proximity of this fold to the field in sec. 36, T. 24 N., R. 8 E., and the attendant probability that the oil and gas bearing sands of that field extend under the Pipeline anticline; by the similarity of the Pipeline anticline to folds in other parts of the Osage Reservation under which small accumulations of oil and gas have been discovered; and by the wide stretch of uniformly dipping beds to the west from which the oil may have traveled eastward to lodge on the crown and under the flanks of the fold. If the conditions that exist in the oil field in sec. 36, T. 24 N., R. 8 E., also hold in the Pipeline anticline, such oil as is produced here will probably come principally from the shallow sands above the Bartlesville sand. If there is any very thick sand below this fold at the general horizon of the Bartlesville it will almost certainly contain an abundance of oil, but in the field to the west the Bartlesville is very thin and has not contributed very much to the total oil output of the district. A possibility that should not be overlooked is that the "Mississippi lime" may carry oil and gas in paying quantity, and one or more tests should be drilled into it regardless of the conditions encountered higher in the stratigraphic column.

A good location for a test well on the Pipeline anticline is near the center of the SW. ¼ SE. ¼ sec. 29; an alternative location is the center of the SW. ¼ sec. 29; a third favorable location is the center of the NE. ¼ sec. 29. At the first location the Fort Scott ("Oswego") limestone should lie between 1,800 and 1,900 feet below the surface, and the Bartlesville sand is probably 300 to 400 feet lower. At the other two locations these beds will be found approximately 100 feet nearer the surface. Any test drilled near the axis of the fold should be bored to a depth of at least 2,600 feet, unless oil or gas in paying quantities is found at shallower depth.

BULLDOG ANTICLINE.

The Bulldog anticline is a low fold of very irregular outline in the west-central part of T. 24 N., R. 9 E. Its branching axis runs northward from the south line of sec. 21 into the SW. ¼ sec. 16, where it forks, one limb going northward and joining the southern extension of the Cottonmouth anticline, and the other westward into sec. 17, where it in turn divides, one limb continuing westward almost to the west line of sec. 17 and the other southwestward across the NW. ¼ sec. 20 into the east side of sec. 19. (See fig. 32.) Along this axis there are three small swells or domes, one in the west-central part of sec. 21, one at the southwest corner of sec. 16, and the third in the SE. ¼ sec. 17. None of these minor folds are in the least prominent, and the total closure of the anticline is but 20 feet; moreover, a fault which cuts across the north flank of the fold may possibly reduce the effective closure to 10 feet. The area inclosed by the lowest closed contour is less than a square mile, but the territory over which the beds are so distinctly arched that they may be considered a part of the anticlinal fold is more than 2 square miles.

No wells have been drilled on this anticline, and as it is several miles from any producing field where the underground conditions are known, it is not possible to state definitely what oil and gas bearing beds may be present beneath the fold. In the oil field near the east line of the township, some 3 miles east of the Bulldog anticline, the Bartlesville sand is well developed and carries oil in abundance, but the shallower sands are not known to contain commercial quantities of either oil or gas. (See discussion of the West Birdseye anticline and of the Fourmile dome.) On the other hand, most of the oil and gas in the field in sec. 36, T. 24 N., R. 8 E., about 3 miles southwest of the Bulldog anticline, come from the sands associated with the Big lime and "Oswego lime," whereas the Bartlesville sand in that field is very thin and carries only small quantities of oil and gas. It seems probable that the Bartlesville sand thins from east to west and that although it probably underlies the Bulldog anticline, it is much thinner there than it is near the eastern edge of the township, and the chances of its yielding large volumes of oil are correspondingly less. The shallow sands, however, will very probably prove to contain oil and gas below the Bulldog anticline, as is indicated not only by their productivity in the field to the southwest but also by their oil and gas content in wells drilled far to the west, northwest, north, and northeast.

The structural conditions in the Bulldog anticline do not encourage the belief that many large oil wells will be obtained on it. The closure is much less and the area within the lowest closed contour much smaller than on the more productive of the Osage anticlines. Nevertheless there is a large area to the west in which the rocks dip uniformly westward and from which oil may have migrated to gather under the crest and along the flanks of the anticline. Furthermore, this anticline is in a zone of pronounced deformation marked by irregular folding and extensive faulting, and similar disturbed zones have been found to be oil bearing elsewhere in Osage County, even where the surface structure is not markedly favorable. This is very probably due to deformation which took place in the deep beds before the deposition of the rocks that now form the surface and which is not reflected save in a general way by the beds that crop out.

Good locations for testing the Bulldog anticline are believed to be the center of the SW. ¼ SW. ¼ sec. 16, the center of the NE. ¼ SW. ¼ sec. 17, just west of the east quarter corner of sec. 19, and the center of the SW. ¼ sec. 21. In the first two and the fourth locations the Fort Scott ("Oswego") limestone should lie between 1,800 and 1,900 feet below the surface, the Bartlesville sand at about 2,150 feet, and the "Mississippi lime" at about 2,300 feet. At the location in sec. 19 the sands should be about 70 feet nearer the surface. Any of these tests must be drilled at least 300 feet into the "Mississippi lime" to be adequate. Elsewhere in the Osage Reservation the expense of drilling wells into the "lime" in areas of good anticlinal structure has almost invariably been rewarded by the production of either oil or gas. The reason for the failure of so many deep tests is that they are poorly located with respect to the structure and are deepened only after they fail to find oil in the shallow beds. The absence of oil in the "Mississippi lime" at these points has no more significance than the dryness of the overlying sands in the same well.

UNFAVORABLE AREAS.

Most of T. 24 N., R. 9 E., is in an area which has been deformed much more than is common in the Osage Reservation. The rocks have been arched in anticlines and domes, bowed down in synclines, and broken by a number of faults. This indicates either that the rocks are incompetent to withstand stresses or that stresses of unusual intensity have been localized in this area. It is probable that deformation was going on long before the deposition of the beds which form the present surface, for geologic history has shown that it is common for stresses to occur in the same general district in successive ages. Accordingly it is not to be expected that the structure of the rocks deep beneath the surface resembles that of the beds which crop out, except in a general way. Although it is reasonable to believe that anticlines in the deep-lying beds underlie anticlines on the surface and that pronounced synclines on the surface overlie synclines in depth, there are probably minor folds in the deep-lying beds which are not reflected at all by similar folds on the surface, and it is quite possible that in such hidden folds there are appreciable pools of oil or of gas. For this reason it is not justifiable to condemn utterly any part of the township, no matter how unfavorable for the accumulation of gas and oil the surface structure may appear. However, there are some parts of the township which should not be drilled unless pools discovered in territory which is structurally more favorable are extended into them. Some of this territory has already been proved barren, at least in the beds above the "Mississippi lime," by wildcat tests, and the relation of these dry holes to pronounced synclines suggests that beds underlying similar synclines are barren.

Particularly unfavorable areas are near the axes of the major synclines which cross the area (fig. 32), including the W. ½ sec. 2, the N. ½ sec. 11, the SE. ¼ sec. 10, the NW. ¼ sec. 15, the E. ½ sec. 16, the SE. ¼ sec 28, the S. ½ sec 32, the SE. ¼ sec. 5, the NE. ¼ sec. 8, the NW. ¼ sec. 17, all of sec. 18, the W. ½ sec. 19, all of sec. 30, the N. ½ sec. 31. the SW. ¼ sec. 31, and the N. ½ sec. 12.

T. 27 N., R. 8 E.

By K. C. Heald.

INTRODUCTION.

The field work on the western half of T. 27 N., R. 8 E. (see fig. 1), was done by the writer in the winter of 1916, and the geologic structure of this part of the township was described in a bulletin issued in February, 1918.[1] The mapping of the township was completed in the spring of 1917 by K. C. Heald, D. E. Winchester, W. B. Emery, and K. F. Mather.

The entire township was mapped with plane table and telescope alidade. Horizontal distances were determined by triangulation and stadia work, and vertical distances by trigonometric and direct leveling.

ROCKS EXPOSED.

GENERAL FEATURES.

The rocks exposed in T. 27 N., R. 8 E., are all of upper Pennsylvanian age and include shales, sandstones, and limestones. (See fig. 34.) The shales predominate but are usually concealed under a mantle of soil and débris from the more resistant limestones and sandstones, so that their character can be learned only from freshly made exposures in stream gullies, road cuts, and other excavations. In general, however, the outcrops of individual sandstone and limestone ledges may be traced long distances, although the entire thickness of a bed is rarely exposed because the soft shales tend to slump so as locally to conceal the underlying rocks. In such places the position of the sandstones and other hard beds is shown only by benches on the hill slopes, where there is no actual outcrop of the underlying bed, although fragments of float from it may litter the surface.

Some of the beds that were most helpful in determining the geologic structure of the township are described in detail below.

[1] Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 57-100, 1918 (Bull. 691-C).

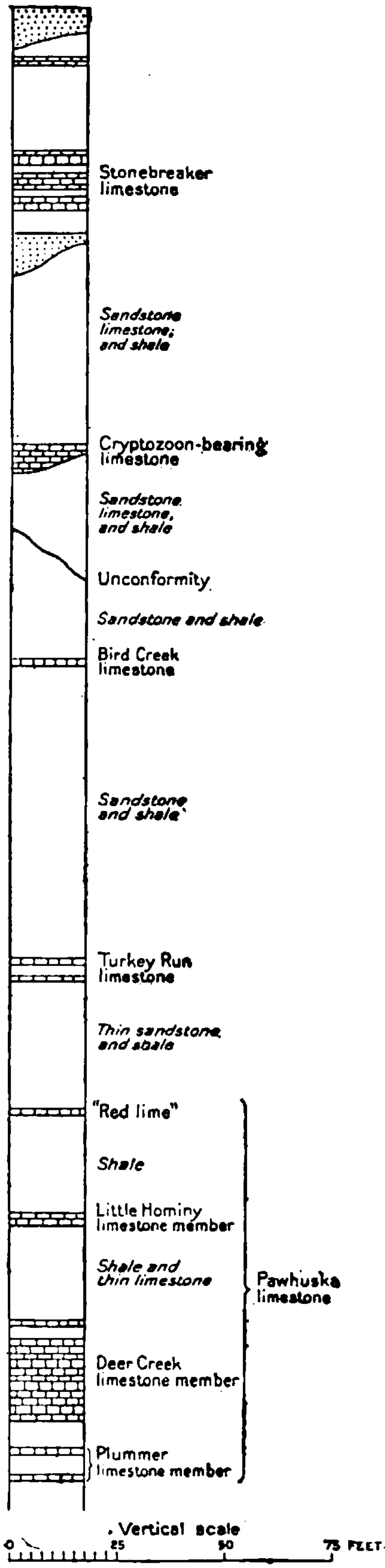


FIGURE 34.—Section of rocks exposed in T. 27 N., R. 8 E.

KEY BEDS.

Stonebreaker limestone.—The Stonebreaker limestone was used as the key bed for determining the geologic structure over much of the northwestern part of the township. Its top is about 250 feet below the base of the Foraker limestone and about 240 feet above the "red lime," which is the highest bed of the Pawhuska limestone. To the north of T. 27 N., R. 8 E., the Stonebreaker seems to consist of a single bed of limestone, but in this township it thickens and is made up of two to four beds of limestone with intervening shales. The thickness of the entire series is about 16 feet near the western edge of the township. The limestone is hard, tough, and sparingly fossiliferous in most localities, but in a few places it has been observed to contain an abundance of *Fusulina*, crinoid segments, and other small fossils; and in the western part of T. 27 N., R. 7 E., there is one bed that also carries many Cryptozoa, some of which have a fragment of a bryozoan as a nucleus. The weathered surface of the Stonebreaker limestone is in most localities strongly stained with limonite, which gives it a dirty-yellow, blotched appearance; the fresh surface is dark blue to light gray, with ocher-yellow limonite stains.

Overlying the Stonebreaker limestone is a marine shale which in places is very fossiliferous. Below the limestone there is a thin shale and a lenticular bed of limestone which ranges in thickness from 1 to 10 feet. The Stonebreaker limestone is named from the Stonebreaker ranch, in T. 29 N., R. 8 E., and is well exposed in the stream bed south of the ranch house.

Cryptozoon-bearing limestone.—The *Cryptozoon*-bearing limestone lies about 70 feet below the top of the Stonebreaker limestone in the northern part of the area and about 60 feet below it in the southern part of the area. North of T. 27 N. the interval between the two is occupied by shale, thin beds of limestone, and a thin bed of sandstone. In T. 27 N. the sandstone thickens and is in places the most prominent bed in the stratigraphic section, capping hilltops and littering the slopes with loose fragments. Some of the intervening limestones are locally prominent and may be of assistance in mapping the structure. None of them appear to be continuous, however, nor have they characteristics which make it possible to recognize them easily and with certainty. Both these last-named qualities are found in the *Cryptozoon*-bearing limestone, and because of them it is of great value in determining the structure of the region.

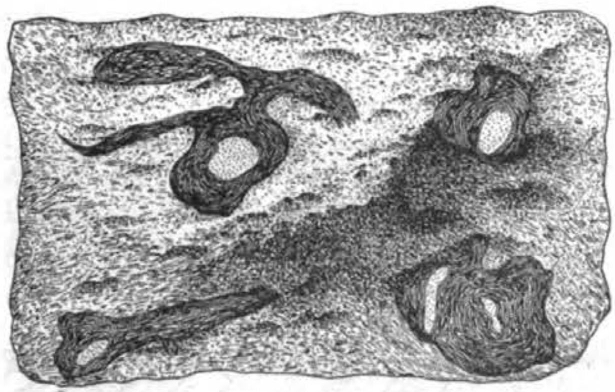


FIGURE 35.—Sketch of rock fragment showing characteristic shapes of Cryptozoa in the *Cryptozoon*-bearing limestone.

The bed is in most places from 1 to 3 feet thick. Although other layers of limestone may immediately overlie or underlie it, they can as a rule be easily distinguished from it by their physical character. The weathered surface of the limestone is usually of a characteristic dark-gray color; the fresh surface a clean dark blue-gray. The limestone is very hard and remarkably brittle and splits almost like glass under the blows of a hammer. It shows a lack of invertebrate fossils which is remarkable in view of the abundance of beautifully preserved forms in beds that may be in direct contact with it. The feature which makes it easily recognized is the presence of Cryptozoa, irregular forms that are the fossil remains of organisms whose nature has not been precisely determined. In many of these forms it is possible to detect a bryozoan, a fragment of shell, or a segment of crinoid stem near the center. These fossil remains were apparently the nuclei around which the Cryptozoa formed. Figure 35 is a rough sketch showing the general appearance of these fossils. Similar forms were seen in the Stonebreaker limestone and in a thin limestone above the Stonebreaker in the southern part of the area. Both these beds, however, are so different in hardness, texture, and other physical characteristics from the *Cryptozoon*-bearing limestone that no confusion can arise.

There is a good exposure of the bed above described in a railroad cut between Pearsons Switch and Blackland. As shown in figure 36, the bed bearing the Cryptozoa is the only one that is continuous. Although it is improbable that this thin bed is absolutely continuous throughout the area, it is apparently very much more nearly continuous than associated beds, and the writer traced it for miles without detecting a break.

A short distance below the *Cryptozoon*-bearing limestone there is an unconformity, and as a result the sequence of beds below it is not even approximately the same in different parts of the area. Where erosion cuts the deepest into the underlying sandstone series hollows were scooped out in which three limestone beds with intervening shales were laid down, but locally one, two, or all three of these limestones may be absent.

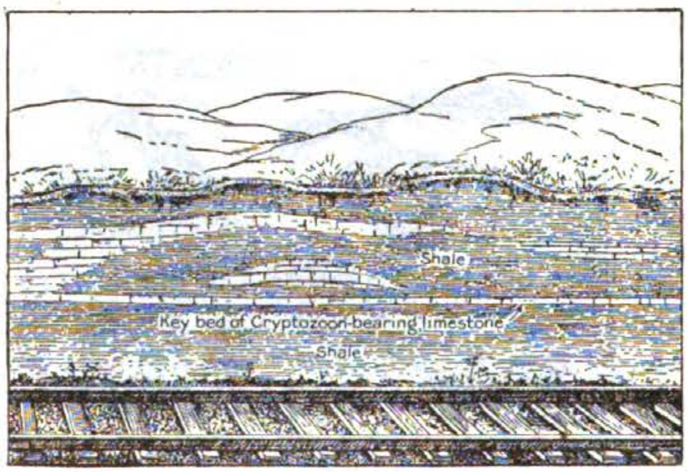


FIGURE 36.—Sketch illustrating conditions observed in railroad cut between Pearsons Switch and Blackland.

West of Pearsons Switch the *Cryptozoon*-bearing limestone is overlain in places by 12 feet of light-gray ocherized fossiliferous limestone, and its dull-gray surface is largely hidden by float from the overlying bed. This overlying bed is lenticular and is similar to beds of less thickness and extent observed in other parts of the area. On the assumption that continuous beds of limestone are laid down on planes that are approximately flat, it follows that if altitudes are taken on the uppermost bed of the overlying limestone instead of on the *Cryptozoon*-bearing limestone, which presumably will be used as a basis for determinations of altitude over much of the surrounding district, an error of 12 feet will be introduced.

Bird Creek limestone.—The Bird Creek limestone, named from its exposure on the valley sides of Bird Creek and its tributaries, is about 50 feet below the *Cryptozoon*-bearing limestone and a little more than 100 feet above the "red lime" at the top of the Pawhuska limestone. In most places where the limestone was seen there is but a single thin bed, about 2 feet thick, but in a few localities there are two beds, separated by about 6 feet of shale. The rock is hard and extremely brittle, so that when struck with a hammer or other hard implement it shatters like glass into chips with sharp edges. Both weathered and fresh surfaces are of a dark bluish-gray color—so dark, in fact, that many samples might justly be called black. Fossil remains may rarely be seen on its weathered surface, but it is nevertheless characterized by a distinct brachiopod fauna, and in practically every locality where it was carefully examined the round, nutlike brachiopod *Enteletes hemiplicata* was discovered embedded in the interior of the limestone.

A good locality for examining the Bird Creek limestone is on the hill slope in the extreme northwest corner of sec. 28, T. 27 N., R. 8 E., just northwest of the large fill where the Midland Valley Railroad crosses Hickory Creek.

Turkey Run limestone.—About 70 feet below the Bird Creek limestone is the Turkey Run limestone, named from its excellent exposures near the head of Turkey Run, in T. 24 N., R. 8 E.[1] It is dark gray to bluish black and is very similar in appearance to the Bird Creek limestone but may be distinguished by the fact that it is in places oolitic and also by the absence of the fossil *Enteletes hemiplicata*. This limestone was used but little in the mapping of T. 27 N., R. 8 E., as it is not well exposed except in the extreme southeast corner, and its outcrop is not shown on the map (Pl. XXXIV). It is excellently exposed on the flanks of the large hill in the northeast corner of sec. 36 and near the south line of sec. 25, also west of the fault in secs. 26 and 35.

"*Red lime.*"—The highest member of the Pawhuska limestone, about 30 feet below the Turkey Run limestone, was called in the field "red lime" because in some places it has a conspicuous outcrop of a rust-red color. Outcrops of similar color were observed in the *Cryptozoon*-bearing limestone and in the Lecompton limestone member, so this color is not in itself a reliable criterion upon which to base the identification of the "red lime." However, the prominent rust-red color is present in comparatively few places, and elsewhere the colors of the weathered and fresh surfaces are distinct from those of the underlying limestones.

The most frequently observed color of the weathered surface of the "red lime" is a distinctive brownish gray; that of the fresh surface a blue-gray with a reddish tinge. The greatest observed thickness of this bed is 7 feet, but the maximum thickness may be considerably greater, as the base of the bed is in most places concealed. In fact, as a rule the bed does not appear as a ledge but as a line of disconnected fragments of float.

[1] Heald, K. C., and Mather, K. F., report on Tps. 24 and 25 N., R. 8 E.: U. S. Geol. Survey Bull. 686-M, 1918.

The rock is very hard and brittle and under a heavy blow splits with a sharp, clean fracture. The bedding is massive, and fragm of float may be of considerable size and are characteristically irregular form. The distribution of fossils in this bed is far fr uniform. At one point the rock may be full of invertebrate remai at another there may be scarcely a trace of ancient life.

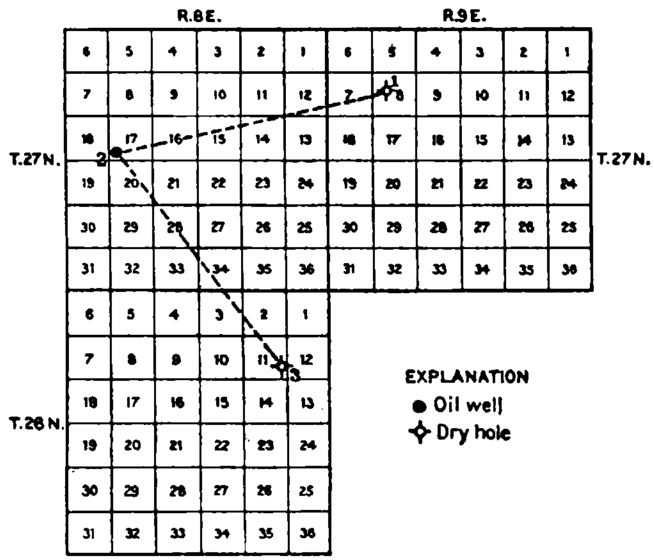


FIGURE 37.—Diagram showing location of wells whose records are given in Plate XXXV.

Above the "re lime" (the topmost be of the Pawhuska limestone) is a series of sandstone. About 25 feet below it are the beds of light-gray limestone that make up the greater part of the thickness of the Pawhuska limestone. This 25-foot interval is in places occupied entirely by shale, but much more commonly it also contains sandstone which is not distinguishable in color and texture from that overlying the "red lime." A very thin limestone, so full of fossil *Fusulina* as to resemble a layer of dirty-yellowish rice, is also present in places and is extremely helpful as a horizon marker.

PENNSYLVANIAN ROCKS NOT EXPOSED.

Below the surface of T. 27 N., R. 8 E., there are about 2,100 feet of sediments of Pennsylvanian age which resemble in general character the outcropping beds and which rest upon the Mississippian limestone. The exact horizon at which the Pennsylvanian rocks stop and the Mississippian rocks begin has not been determined, although it is known that the limestone called the "Mississippi lime" by drillers is either very near the top or at the top of the Mississippian series. The general sequence is shown graphically in Plate XXXV. The locations of wells whose logs are reproduced on this plate are shown in figure 37.

SANDS CONTAINING OIL OR GAS.

In the Pearsons Switch field, from which comes the only oil and gas produced in T. 27 N., R. 8 E., and in the Myers gas field, which is in the extreme northeast corner of T. 26 N., R. 8 E., most of the

BEARING STRATA.

gas comes from a series of sands the highest of which is about 630 feet below the Stonebreaker limestone and the lowest about 420 feet lower. Below these sands there is a barren series, about 670 feet thick, of alternating sandstones and shales, and next a sand about 30 feet thick which was reported to carry gas in one of the deep wells that has been drilled on the Pearsons Switch anticline, although no attempt has ever been made to utilize the gas.

Underneath this gas-bearing sand there is a heavy bed of shale, succeeded by a series of limestones and shales with very little sandstone. One bed of limestone about 2,100 feet below the Stonebreaker limestone carries gas and has given a showing of oil below the Pearsons Switch anticline, and from this circumstance, as well as from the relation of this bed to an underlying series of dark shales, it seems probable that this limestone occupies the general horizon of the Fort Scott ("Oswego") limestone. Some 360 feet lower there is a heavy limestone which carries both gas and oil under the Pearsons Switch anticline and which has given showings of oil in deep wells at short distances to the east and to the south of T. 27 N., R. 8 E. This bed is almost undoubtedly the "Mississippi lime," which yields oil in the fields near Pawhuska and farther east in the Osage Reservation.

STRUCTURE.

The rocks exposed in T. 27 N., R. 8 E., have a general westerly dip of about 35 feet to the mile. This dip is fairly uniform over much of the township but is modified in the south-central and west-central parts by the Hickory Creek and Pearsons Switch anticlines, on the flanks of which the rocks dip to the north, east, and south as well as to the west.

HICKORY CREEK ANTICLINE.

The Hickory Creek anticline is a rather small plunging anticlinal fold whose axis extends from a point near the north quarter corner of sec. 27 northwestward to the NW. ¼ sec. 21. (See fig. 38.) It is a gentle fold, and the rocks dip smoothly to the northeast and southwest from the axis, which plunges to the northwest. There is no easterly dip along the axis.

At the time the field work on T. 27 N., R. 8 E., was completed no drilling had been done on this fold, but it is understood that more recently at least two wells have been drilled near its axis. It is reported that one of these wells found gas in paying quantity and had an initial production of 2,000,000 cubic feet a day. It is not known from what sand this gas was obtained, but probably it came from one of the shallow sands that yield gas in the Pearsons Switch field, 2 miles to the northwest. Nothing is known concerning the other well.

The structural conditions on this fold do not lead to a belief that it has been effective in bringing about the formation of any large pool of oil, for although similar anticlines which have no closure on the east have been found to overlie oil pools in other parts of the Osage Reservation, these pools have almost invariably yielded only moderate amounts of oil, even where the sand conditions are believed to be distinctly favorable. In view of the fact that a well drilled to the "Mississippi lime" on the Pearsons Switch anticline, only a mile west of the Hickory Creek anticline, yielded a large quantity of oil, it seems justifiable to recommend a test to the "Mississippi lime" on the Hickory Creek anticline, even though the structural conditions are not pronouncedly favorable. It should be borne in mind that the geologic structure is only one of the several factors which control the location of an oil or gas pool and that some one of the other factors may greatly enhance the value of territory where the surface indications are not particularly encouraging. Furthermore, the Hickory Creek anticline is believed to lie in a general zone of weakness along which some movement with consequent folding took place before the deposition of the rocks that are now at the surface, and this folding may well have resulted in the formation of anticlines which arch the "Mississippi lime" but are not reflected except in a general way by the surface structure. Such concealed anticlines are just as likely to have trapped large quantities of petroleum or gas as any of the well-developed anticlines that appear at the surface.

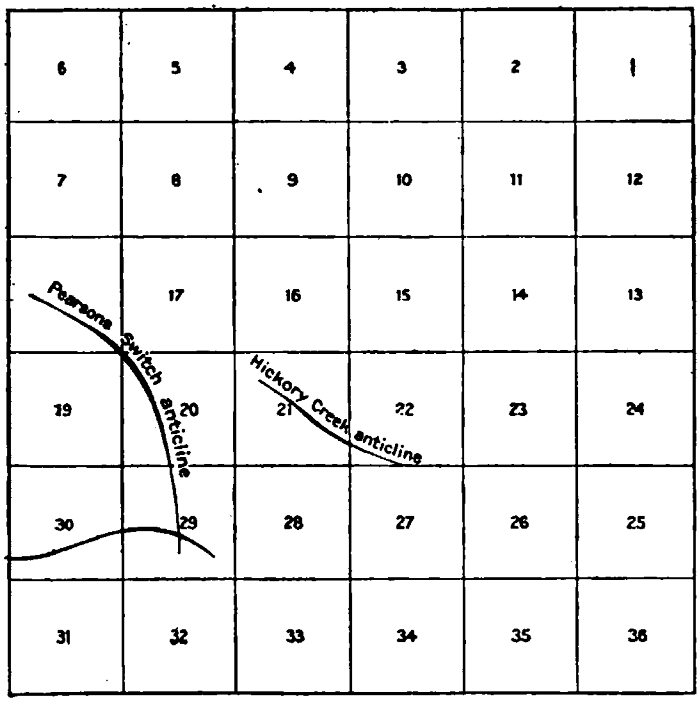


FIGURE 38.—Diagram showing position of anticlinal axes in T. 27 N., R. 8 E.

A good location for a test well on the Hickory Creek anticline is near the center of sec. 21. Wells drilled at this location should encounter the productive sands of the Pearsons Switch field at a little less depth than that at which they were found in well No. 52, sec. 17. (See Pl. XXXV.)

PEARSONS SWITCH ANTICLINE.

The Pearsons Switch anticline, named from its proximity to Pearsons Switch, on the Midland Valley Railroad, is by far the most pronounced fold in the township. It lies in secs. 17, 18, 19, and 20, and on its flanks are two small subsidiary domes, one in sec. 29 and the other in sec. 30. The highest point of the fold appears to be in the extreme southeast corner of sec. 19, and from this point the beds slope in all directions but most steeply to the northeast, where for a short distance the dip is about 100 feet to the mile. The vertical component of this dip is about 40 feet. The outline of the anticline is rather irregular, showing several spurs or scallops, the most pronounced of which is a long eastward-trending point at the extreme north end of the fold. The anticline is capped by a heavy sandstone that lies some 18 feet below the top of the Stonebreaker limestone. The shape of the fold was determined by elevations taken on this sandstone and on the *Cryptozoon*-bearing limestone, which crops out on the western, southern, and eastern flanks. It is possible for confusion to arise in mapping this anticline, as both above and below the *Cryptozoon*-bearing limestone there are beds of limestone which resemble it closely in color and brittleness. Also there is an unconformity below the *Cryptozoon*-bearing limestone, and the character of the beds a short distance below it may be entirely different at two closely adjacent localities.

The minor domes southeast and southwest of the main anticline are both low, oval, smoothly outlined folds. The eastern one, in sec. 29, has an axis about three-quarters of a mile long, trending northwest. The dip to the northeast does not exceed 10 feet in vertical amount and is at the rate of about 60 feet to the mile. That to the southwest is a little steeper. On the northwest and southeast the dips are extremely gentle. This dome is capped by the same sandstone that crowns the main Pearsons Switch anticline, and the structure was outlined from elevations on this sandstone and on the *Cryptozoon*-bearing limestone, which crops out to the north, east, and south. No actual dips to the northeast were seen, and the correctness of the mapping depends on that of the measured interval between the top of the sandstone and the top of the limestone.

The dome in the southwest corner of sec. 30 is more pronounced than the one just described, although it is not so large. This small dome is superposed on an anticlinal fold whose flanks dip to the northwest, southwest, and southeast but not to the northeast. The axis of this fold is more than a mile long and pitches southwest, and the steepest dip is in that direction. The dome is capped by the Stonebreaker limestone, and elevations on this limestone, supplemented by observations on the sandstone lying a short distance below it, were used in determining the structure. At this place the

Stonebreaker limestone is in two beds about 8 feet apart, and care must be taken not to confuse them.

The sands that yield oil and gas under the Pearsons Switch anticline are described briefly in a preceding paragraph (pp. 218–219), and their positions are shown graphically in Plate XXXV. Two oil wells have been drilled into the "Mississippi lime" on this anticline. The first one, whose record is given on Plate XXXV, is in the southwest corner of sec. 17, not far from the center of the crown of the dome. It penetrated about 30 feet into the "Mississippi lime," which yielded both oil and gas. Its initial production was 400 barrels a day. On November 6, 1918, a second well on this anticline obtained oil from the "Mississippi lime." The initial production was 7,000 barrels a day, and the yield is reported to have declined to about half that amount in four weeks. This well, which is not shown on Plate XXXIV, "offsets" the first well to the south. It is possible that elsewhere in this general locality a limestone layer which lies about 350 feet above the "Mississippi lime" and which has yielded showings of both oil and gas may contain commercial quantities of these minerals. There is also a possibility that deeper beds than any that have been reached by wells drilled in this general region may also contain oil and gas. The possibilities of the Pearsons Switch anticline can not be considered established until wells have been drilled at least 300 feet into the "Mississippi lime."

In view of the good results attained by drilling to the "Mississippi lime" on the main dome of the Pearsons Switch anticline it seems justifiable to drill similar tests on the two subsidiary domes to the south. Good locations for these tests are near the middle of sec. 29 and at the center of the SW. ¼ sec. 30. At the location in sec. 29 the "Mississippi lime" should be encountered at a depth of about 2,500 feet; at the other one it will probably be a little deeper.

UNFAVORABLE AREAS.

Over a large part of T. 27 N., R. 8 E., the geologic structure of the surface rocks is not such as is usually found in beds that overlie pools of oil or gas. Most of this township except the areas on or immediately adjacent to the two anticlines described above and a narrow strip near the eastern edge of the township may be classed as unfavorable. The unfavorable area includes secs. 2, 3, 4, 9, 10, 15, and 16, the S. ½ secs. 31 and 32, and all of secs. 33 and 34. This does not necessarily mean that there is no oil or gas under these portions of the township, but rather that they are so much less favorable than the remainder that it would not be justifiable to drill them unless exploration of the territory which is structurally more promising results in the finding of oil or gas fields that may be extended into these areas.

T. 26 N., R. 8 E.

By K. C. Heald and Kirtley F. Mather.

INTRODUCTION.

The greater part of the field work in T. 26 N., R. 8 E. (see fig. 1), was done by the writers during the months of June and July, 1917. D. E. Winchester and W. B. Emery collaborated in the mapping of the eastern part of the township. Plane-table and telescopic alidade were used throughout the area.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL FEATURES.

The rocks exposed in this township are all of upper Pennsylvanian age and include sandstone, limestone, and shale. Sandstones and shales constitute the greater part of the exposed strata, but limestone beds occur at a number of horizons from the top nearly to the bottom of the section. Certain of these limestones are especially noteworthy for their conspicuous outcrops in many parts of the township. A generalized geologic section indicating the nature of the exposed rocks and the intervals between the successive beds of sandstone and limestone is presented in figure 39. The vertical intervals there recorded are approximate averages for the region under discussion; they vary somewhat from place to place throughout the township.

The geologic structure was determined from elevations taken on a great number of beds. Some of these have only a very local development, but others may be traced for long distances. The more persistent and helpful of these key beds are described briefly in the following paragraphs.

KEY BEDS.

Plummer limestone.—Throughout this township the Plummer limestone is an easily recognized and very persistent bed, 3 to 5 feet in thickness, occurring about midway between the Deer Creek and

Lecompton members of the Pawhuska limestone. It was named[1] from its occurrence near the Plummer ranch, in T. 26 N., R. 9 E., and has proved to be an excellent key bed throughout a considerable part of these two townships. Its top is about 20 feet below the top of the Deer Creek limestone, the most conspicuous member of the Pawhuska formation and the bed to which the name "Pawhuska lime" is ordinarily applied by commercial geologists working in this region. Good exposures may be observed almost anywhere in the southeastern part of T. 26 N., R. 8 E., a few feet below the rim of the inner valley of North Bird and Middle Bird creeks.

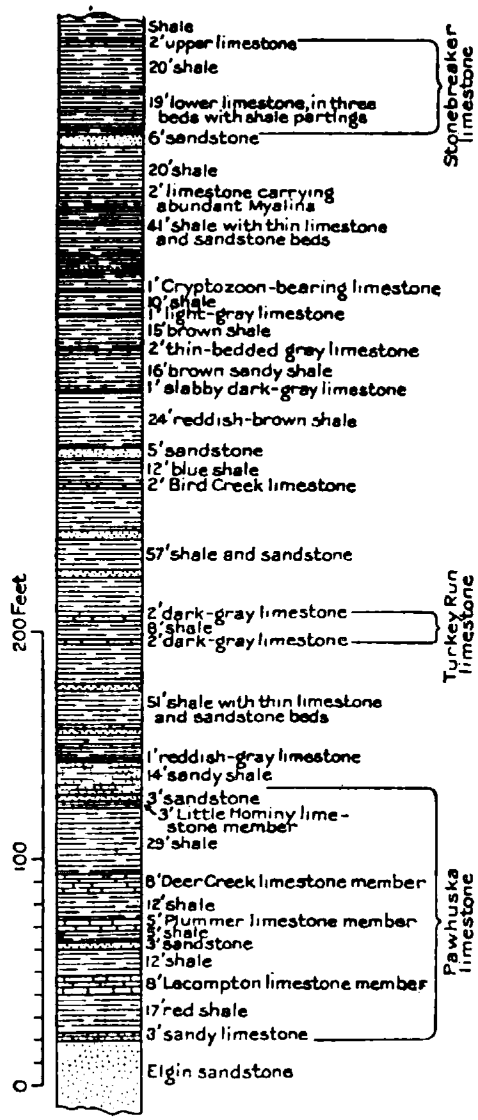


FIGURE 39.—Columnar section showing rocks exposed between the east and west margins of T. 26 N., R. 8 E.

This bed is at most localities a very hard, brittle fine-grained limestone, which weathers into large rectangular slabs 5 to 15 feet in length; these slabs sometimes slide unbroken down the slopes and may appear to be in place many feet below the actual cropping of the bed. The color of the weathered surface is dark brownish gray, spotted with limonitic stains; on freshly fractured surfaces the stone is lead-gray. The limestone is not conspicuously fossiliferous but in places contains brachiopod and other shells.

The Plummer limestone is readily identified because of its position, 10 to 18 feet below the ledge almost everywhere formed by the Deer Creek limestone. It was used as a key bed in preference to the higher and more conspicuous limestone because of the difficulty in ascertaining one's exact position with respect to any single horizon in the Deer Creek member. The top of that member is generally concealed somewhere along the gentle slopes on the surface of the intervalley table-lands that have resulted from the marked difference

[1] Clark, F. R., report on T. 26 N., Rs. 9, 10, and 11 E.: U. S. Geol. Survey Bull. 686–I, 1918.

in resistance to erosion offered by the limestone and the overlying shales. These upland flats are rimmed by conspicuous ledges of the Deer Creek limestone, but different beds within the member are the ledge makers at different places. The use of the Deer Creek ledge as a datum plane involves a possible vertical error of not less than 5 feet, whereas the upper surface of the Plummer limestone may be located quickly and accurately with a possible error of only a few inches.

Little Hominy limestone.—The Little Hominy limestone is a 3-foot bed, which in this township lies about 30 feet above the Deer Creek limestone. Typically it is light gray on weathered surfaces, somewhat darker where freshly broken, and very coarsely crystalline. In many places the uppermost 3 to 6 inches of this member consists of very impure conglomeratic limestone containing many shell fragments and worn pebbles of limy material. At certain localities *Fusulina*, brachiopods, gastropods, and other organisms are well preserved in this limestone, but at most places good fossils are lacking.

At some of its exposures the Little Hominy is unusually sandy, containing from 20 to 30 per cent of clear, glistening quartz grains. In places this proportion is greatly exceeded and it is impossible to separate the limestone from the overlying massive sandstone, a bed which in the absence of the Little Hominy limestone has proved very serviceable in detailed mapping. It is probable, too, that the abrupt disappearance of this limestone at many localities is due to its transition from a sandy lime into a calareous sandstone that is indistinguishable from the overlying sands. Good exposures may be observed on both sides of the north-south ridge in the middle of sec. 14, T. 26 N., R. 8 E., and on the hillside west of the road in the NW. ¼ sec. 35 and the SW. ¼ sec. 26.

Turkey Run limestone.—From 70 to 80 feet above the Little Hominy member of the Pawhuska limestone is a dark-gray limestone, 1 to 2 feet thick, to which the name Turkey Run limestone has been applied,[1] from its excellent exposures near the head of Turkey Run, in T. 24 N., R. 8 E. In the southern part of T. 26 N., R. 8 E., as well as in the townships farther south, this limestone is fine grained, thin bedded, hard, and brittle and weathers into smoothly rounded slabs a few inches in length. The weathered surface is generally light gray with many curving traceries and irregular patterns of darker gray or yellowish brown due to the fragments of brachiopod and gastropod shells, the margins of which are thus etched by weathering. On fresh fractures the color is a much darker blue-gray, at some localities almost black. Well-preserved fossils are extremely rare; in fact, this bed can most readily be distinguished from the

[1] Heald, K. C., and Mather, K. F., report on Tps. 24 and 25 N., R. 8 E.: U. S. Geol. Survey Bull. 686–M, 1919.

lithologically similar limestone 60 feet higher in the section by the absence of the brachiopod species commonly found in the higher bed.

In the central and northern parts of T. 26 N., R. 8 E., the Turkey Run limestone is split into two beds separated by 5 to 9 feet of limy shale. The lower bed is 2 or 3 feet thick and consists of rather soft oolitic limestone, which contains few fossils and weathers into thin slabby masses with a dark dirty-gray surface. On fresh fracture this limestone appears dark gray, with scattered blotches of limonitic material. The upper bed, the top of which is 81 feet above the top of the Little Hominy limestone, is hard, dense, and tough and weathers into solid chunks of irregular shape with sharp corners. Weathered surfaces are dirty gray with numerous irregular stains of yellow and brown limonite; freshly fractured surfaces are light gray with a lavender tinge. The bed is capped by about 2 feet of thin, slabby limestone or calcareous shale. Both beds are well exposed in the SW. ¼ sec. 22. Exposures in the NW. ¼ sec. 15, although more difficult of access, show the entire series of strata from the beds below the Little Hominy to the beds above the Bird Creek limestone.

Bird Creek limestone.—The next limestone above the Turkey Run bed, just referred to, has been named the Bird Creek limestone,[1] for there are many good outcrops along the headwaters of Bird Creek and its main branches in the township under consideration. Typical exposures occur along the south side of South Bird Creek in sec. 29 and on both sides of Middle Bird Creek in sec. 8. The interval between the Turkey Run and Bird Creek limestones varies between 55 and 65 feet within this township and is in general slightly greater in the northeastern part of the township than along the south margin, although it increases again in the townships farther south.

The Bird Creek limestone is in general appearance very similar to the Turkey Run limestone as it occurs in the vicinity of the southern boundary of T. 26 N., R. 8 E. The higher bed is only slightly darker than the lower and weathers into similar smoothly rounded slabs a few inches in diameter and with gray surfaces. On fresh fractures the stone appears dark blue-gray or almost black. It contains rather abundant remains of the brachiopod *Enteletes hemiplicata*, specimens of which may generally be found by breaking up the weathered fragments at any outcrop. In the region under discussion the presence of this fossil has proved to be diagnostic of this limestone.

The Bird Creek limestone is only a foot or two in thickness, and on many gentle hill slopes it remains entirely concealed beneath the grass-covered soil for long distances along its line of of outcrop.

[1] Heald, K. C., and Mather, K. F., op. cit.

Under these conditions, where float from this limestone can be discovered by careful search only at intervals of a hundred yards or so, its position may frequently be traced by its effect upon vegetation. Brown patches of sun-burned grass in the midst of the green pastures of this township commonly indicate the presence of limestone immediately below the shallow surface soil, and in the region underlain by the Bird Creek limestone they lead unerringly to inconspicuous croppings of that bed.

Cryptozoon-bearing limestone.—Limestone beds occur at closely spaced intervals throughout the stratigraphic series above the Bird Creek limestone. Many of them are lenticular and of small extent, and few display lithologic or paleontologic features that readily distinguish individual beds from those higher or lower in the series. Fortunately, however, the most persistent and extensive of these many limestones is also one which may easily be recognized by its fossil content and general appearance. This is the *Cryptozoon*-bearing limestone, a bed 1 to 2 feet thick, about 90 feet above the Bird Creek limestone. Its characteristic features are well displayed in the outcrops near the base of the flat-topped hills west of the north-south road in secs. 7 and 18.

Typically this limestone is very hard and remarkably brittle and splits almost like glass under the blows of a hammer. The weathered surface is usually of a characteristic dark-gray color; the fresh surface a clean dark blue-gray. The feature which makes it easily recognized is the presence of Cryptozoa, irregular forms that are the fossil remains of organisms whose nature has not been precisely determined. In many of these forms it is possible to detect a bryozoan, a fragment of shell, or a segment of crinoid stem near the center. These fossil remains were apparently the nuclei around which the Cryptozoa formed. A rough sketch showing the general appearance of these fossils has been presented in an earlier paper[1] describing the geology of the region immediately north of this township.

UNEXPOSED ROCKS.

The lowest formation exposed at the surface within T. 26 N., R. 8 E., is the Elgin sandstone, into which the larger streams in the eastern part of the township have incised their valleys. Information concerning the strata below this sandstone depends on well records and is not nearly as complete as is desired. At the date of writing only three wells have been drilled to depths greater than 1,250 feet, and the log of only one of these is now available. The scanty data at hand must therefore be supplemented by information from the neighboring townships. (See fig. 40.)

[1] Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, fig. 24, p. 65, 1918 (Bull. 691-C).

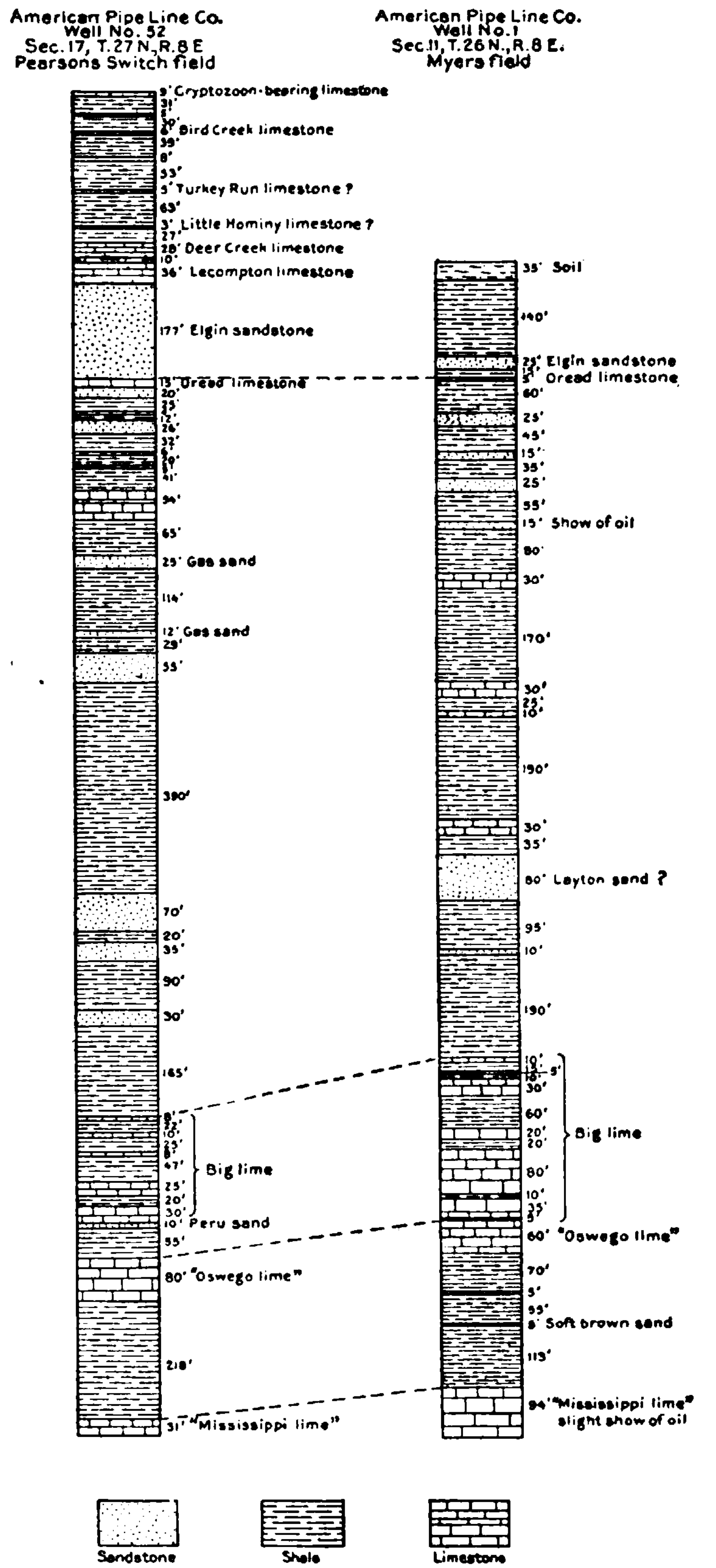


FIGURE 40.—Logs of selected wells in Tps. 26 and 27 N., R. 8 E.

The Pennsylvanian rocks below the Elgin sandstone are of the same general type as those which appear on the surface. Sandstone and shale make up about 80 per cent of the total thickness of beds above what is known to the drillers as the Big lime (probably the Pawnee limestone of the Kansas section). Below that horizon there is comparatively little sandstone, but there are massive beds of limestone and thick series of shale.

Most of the sandstones in the upper part of the stratigraphic section seem to be lenticular, varying greatly in thickness or pinching out entirely within short distances. Two beds, however, appear to be more persistent and will doubtless be encountered wherever wells are drilled in the northeast quarter of the township, if not throughout its extent. The upper of these two sandstones is reached at depths of 175 to 350 feet in the gas field near Myers, in sec. 12, and is between 250 and 300 feet below the Plummer limestone; it contains much water, which at most localities is fresh. The other persistent sandstone is 250 to 300 feet lower in the series and under favorable conditions yields large quantities of gas. It is one of the most productive of the sands in the Myers gas field and is probably at the same horizon as that occupied by the chief gas sand in the Pearson Switch field, 6 miles to the northwest. Below this gas sand are 500 feet of strata which consist largely of shale with a few thin beds of limestone or sandstone. Certain of these sandstones are said to contain gas or water, but none are of economic importance. Underlying this shale series, at a depth of approximately 1,100 feet below the Plummer limestone, there is a series, about 100 feet thick, which consists predominantly of sandstone and limestone with only minor amounts of shale. The deepest gas-bearing sands in the Myers gas field are included in this series, which is apparently the stratigraphic equivalent of the Layton sand of the oil field near the southeast corner of T. 24 N., R. 8 E. The next 350 feet of strata are almost entirely shales, but they are underlain by a thick mass of limestone, broken at frequent intervals by shale partings. This represents the Big lime of the drillers and probably includes also the "Oswego lime" or Fort Scott limestone, although an alternative interpretation might be to identify a 5-foot lime shell, 70 feet lower, as the "Oswego lime." The one record now available indicates that sands are absent at the horizons where the Peru and Wheeler sands occur in the oil fields to the east and south, although 6 miles to the northwest there is a 10-foot sand in the same stratigraphic position as that occupied by the Peru. A sandstone 5 feet thick, 130 feet below the bottom of these limestones, is the only sand reported between the Big lime and the "Mississippi lime" and may possibly represent the Bartlesville sand, although it is more probably a sandy lens of small extent occurring at a level slightly above that of the Bartlesville.

Nearly 2,200 feet below the top of the Deer Creek limestone is a hard oil-bearing limestone—the "Mississippi lime," as that term is applied throughout the Osage Reservation. It was penetrated for nearly 100 feet in the comparatively deep well on the margin of the Myers field, in sec. 11. The interval between the "Mississippi lime" and the formations that crop out at the surface in the western part of the Pawhuska quadrangle is about 250 feet less in T. 26 N., R. 8 E., than in the townships to the south and east. Presumably the absence of the Bartlesville sand is closely connected with this fact, for which a number of plausible explanations at once suggest themselves. If it is true, as seems likely, that this variation is due partly to the irregularities of surface of the Mississippian floor upon which the Pennsylvanian sediments were deposited, it follows that the petroliferous beds that lie 200 feet or more below the top of the "Mississippi lime" in the eastern part of the Osage Reservation may be expected at much greater depths below that horizon in this township. Many more data must be gathered before the exact relations can be known with certainty.

STRUCTURE.

SALIENT FEATURES.

The strata which appear at the surface in T. 26 N., R. 8 E., are in general tilted downward in a direction a little north of west, so that any individual bed is about 250 feet higher at the east margin of the township than at the west. This regional slope is very much modified by local warping, which has developed several anticlinal and synclinal folds, and by a number of faults, each with the northwest strike characteristic of faults throughout the Osage Reservation. The faults are of short extent and slight throw and are confined to the eastern half of the township, where deformation is much more intense than in the western half.

The structure is shown on the map (Pl. XXXVI) by 10-foot contours, based on surface data and drawn to represent the attitude of a hypothetical bed 548 feet below the top of the Plummer limestone. This datum plane coincides with that used to represent the structure of the townships on the north, east, and south. A different datum was used for the work in T. 26 N., R. 7 E., and because of divergences between certain beds the contour lines on the two datum planes do not coincide along the boundary between these two townships.

ANTICLINES AND DOMES.

MYERS DOME.

One of the most perfect domelike uplifts in the Osage Reservation is situated near Myers, in the northeast corner of this township. The fold is a symmetrical oval with its longer axis extending eastward from the NE. ¼ sec. 11, T. 26 N., R. 8 E., through the NW. ¼ sec. 7, T. 26 N., R. 9 E. The closure is about 80 feet. The lowest closed contour is the 420-foot line and incloses about 1½ square miles within these two townships, including nearly all of sec. 12 and adjacent parts of secs. 1 and 11 in T. 26 N., R. 8 E. The apex of the dome is in the SW. ¼ NE. ¼ sec. 12. Structurally the Myers dome is ideal for the localization of an oil pool of large volume.

Toward the west, the direction from which oil and gas migrating up the regional slope would come, this dome is hemmed in by a series of low anticlinal folds separated from it by a shallow synclinal trough. These folds must necessarily interfere with the free movement of oil and may possibly limit the gathering ground available as the source of an oil pool beneath the Myers dome to less than 4 square miles. Possibly, also, the three faults in secs. 2 and 11 may assist in cutting off the supply.

To date seven gas wells and five dry holes have been drilled on this dome. An additional dry hole has been sunk on the floor of the syncline north of the anticlinal fold in the NE. ¼ sec. 1. Drillers' logs for all but three of these holes are at hand. Only one was sunk below the horizon of the Layton sand. The first well drilled in sec. 12, located squarely on the crest of the dome, had an initial production of 15,000,000 cubic feet of gas from a sand 25 feet thick, which was reached at a depth of 535 feet; gas is also reported to have been present in two other sands at shallower depths in this well. Other wells, nearly as favorably located with respect to structure, failed to obtain gas in paying quantities from this sand at 500 to 600 feet. Some of these wells were continued or subsequently deepened to approximately 1,200 feet, where an alternating series of sandstones, limestones, and shales seems to represent the horizon of the Layton sand. Gas in paying quantities was obtained from the sands in this series in a few of these wells, but not in all. Apparently, these sands are "tight" in spots, so that they vary greatly in gas-yielding capacity. A "showing" of oil is reported from the "500-foot" sand in one well; in another there was a similar "showing" from a sand about 200 feet lower; and in still a third well there was a "light showing" of oil from the "1,200-foot" sand. The "500-foot" sand is apparently at the same stratigraphic horizon as that occupied by the best-paying gas sand in the Pearsons Switch field, 6 miles to the northwest.

The dry hole in the SE. ¼ sec. 11 is 2,172 feet deep; its log is graphically shown in figure 40. Several shallow sands yielded water or slight amounts of gas or oil; a sand 80 feet thick, presumably the Layton sand, reached at 1,095 feet, yielded salt water; no trace of oil or gas was reported from the Big lime or the "Oswego lime," nor were there any sands reported associated with them; 5 feet of soft brown sand was penetrated 118 feet above the "Mississippi lime," but no oil or gas was reported to be present in it. The "Mississippi lime" was reached at 2,078 feet and penetrated to a depth of 94 feet; a "slight show" of oil was observed at a depth of 2,108 feet. On July 6, 1917, seven months after the well was completed, the sludge pit still showed a considerable quantity of oil, and gas was escaping from the plugged hole. The record does not state whether the hole was shot. This well is far down the western flank of the Myers dome, just below the lowest closed contour. Although this is not the most desirable location for a deep test, it is nevertheless true that if a large oil pool had been trapped by this structure in the strata penetrated by this well a good yield might have been expected there. The test, although not conclusive, is distinctly unfavorable to the prospects of this dome.

Apparently the only rocks present beneath the Myers dome which are likely to yield oil in commercial quantities are those of the "Mississippi lime." In many places throughout the Osage Reservation east and south of this township good yields have been obtained from "sands" in this limestone at different levels within 300 feet of its top. Some of the best-paying sands are as much as 200 feet below its surface, in a zone which has not been penetrated in the Myers field. A well 6 miles to the northwest, in the Pearsons Switch field, is reported to have had an initial daily production of 5,000 barrels or more from the upper 31 feet of this limestone. Adequate tests should therefore be made in this locality.

Although certain of the minor flexures present at the surface in the Osage region may not persist at depths of 2,000 or 3,000 feet, there can be no doubt that so prominent a fold as the Myers dome arches the Mississippian strata, nor can its competency to form a reservoir for oil and gas be doubted. The uncertain factors are the presence of suitable sands within those strata and a source from which the oil may be derived. In view of the general experience that production from limestones is apt to be "spotted," it is strongly recommended that at least two more tests be made of the deeper strata in the Myers dome. The holes should penetrate to a depth of at least 400 feet below the top of the "Mississippi lime" and should be located between the 440 and 470 foot contour lines. The location of well No. 9, the dry hole near the middle of the south line of the NW. ¼ sec. 12, is good; this well was abandoned at 1,147 feet, at the horizon of the Layton sand. If deepened, it should reach the "Mississippi lime" at about 2,000 feet and should be continued to 2,450 feet unless oil in paying quantities is found before that depth is reached. Another suggested location for a deep test is in the NW. ¼ NW. ¼ NE. ¼ sec.

12, where the depth to the "Mississippi lime" would be about the same as that estimated for well No. 9.

BENCHMARK ANTICLINE.

A small flexure extends north-northeastward, parallel to the regional strike of the rocks in this township, from the NE. ¼ sec. 10 to the NW. ¼ sec. 2. It is separated from the Myers dome by a syncline which abruptly terminates at either end against a fault. The closure of about 15 feet is sufficient to trap an oil pool that would supply wells of small production if other conditions are favorable. This fold is 1½ miles nearer the Pearsons Switch field than the Myers dome, and it is possible that the "Mississippi lime" might yield oil in commercial quantities in this smaller anticline, even though it failed to do so in the more prominent dome. The test should be made at the apex of the doubly plunging anticline, about 400 feet east and 1,600 feet north from the southwest corner of sec. 2. At that locality the top of the "Mississippi lime" is probably between 2,300 and 2,400 feet below the surface.

CAIRN TERRACE.

Extending southwestward from the Myers dome is a broad, flattened anticlinal nose which may be classified as a terrace in spite of the irregularities of its surface. It occupies much of the S. ½ sec. 11 and the N. ½ sec. 14 and extends into the NE. ¼ sec. 15. Its surface displays two small bulges, each of which causes a contour line to close. (See map, Pl. XXXVI.) Structurally this terrace is favorable for the accumulation of oil; its gathering ground is much more extensive than that contributory to the Myers dome. From present knowledge, however, nothing commendatory can be said with certainty concerning the oil-bearing possibilities of the formations beneath it. Should it prove advisable to test this terrace suitable locations will be found near the north quarter corner of sec. 14 and in the NE. ¼ NE. ¼ NE. ¼ sec. 15.

DISAPPOINTMENT DOME.

Parts of secs. 21, 22, 27, and 28 are included in a triangular anticlinal fold which has an easterly dip of about 50 feet and a closed area of more than a square mile. Structurally this fold ranks second only to the Myers dome in this part of the Osage Reservation, and in extent of gathering ground from which oil could migrate it is far superior to that dome. Since the completion of the field work on which this report is based two wells have been drilled on this fold. One, indicated on the map, is reported to be at the center of the SE. ¼ sec. 21 and was abandoned at a depth of 2,726 feet. This depth would carry the drill about 400 feet into the "Mississippi lime." The location of this test, a short distance down the west flank of the dome, is excellent, and its failure indicates that there is grave doubt as to the presence of sands carrying commercial quantities of oil in the "Mississippi lime" beneath this part of the township. The second hole was drilled in sec. 22 and was abandoned at 2,420 feet, in the "Mississippi lime"; it is not shown on the map. On account of the irregular occurrence of oil in most limestones, it might be well to make still another test of this dome before definitely classifying the area as unproductive. It is suggested that such a test, if made, be located at a point about 800 feet south of the north line and 2,000 feet west of the east line of sec. 21. The hole should be drilled to a minimum depth of 2,700 feet.

BASELINE ANTICLINE.

Separated from the Disappointment dome toward the south by a low saddle athwart the course of South Bird Creek is a broad, flat-crested fold of slightly smaller dimensions, which occupies the S. ½ sec. 28 and nearly all of sec. 33. Only two contour lines on this fold are closed, but the easterly dip amounts to more than 40 feet. The beds rise steeply from the west toward its summit, flatten into a broad arch, and descend gently to the bottom of a fault-shattered syncline on the east. The structure seems admirably suited to bring about the accumulation of an oil pool, which might be expected to underlie all of the area inclosed by the 300-foot contour line south of South Bird Creek and to extend some distance down the steep slope toward the west. The failure of the tests made on the Disappointment dome, however, indicates the probability that suitable reservoir sands are absent here as well as there. In spite of this, the Baseline anticline is worthy of at least two test wells. Good locations for these are in the SW. ¼ SW. ¼ sec. 28 and the NW. ¼ SW. ¼ sec. 33. To be adequate they should be drilled to depths of 2,650 and 2,750 feet respectively.

COYOTE DOME.

The SW. ¼ sec. 24 and the NW. ¼ sec. 25 are underlain by a small domelike flexure with a closure of about 20 feet. Although of slight extent and not especially well located with respect to gathering ground, it is not unworthy of notice. The nearest well is a dry hole, less than a mile to the east, in the NW. ¼ NW. ¼ sec. 30, T. 26 N., R. 9 E., near the bottom of a syncline. This hole is reported to have had a "show of oil" from the "Oswego lime" and to have been abandoned in the "Mississippi lime" at 2,292 feet. This would mean that it penetrated the deeper lime for only a few feet and is not an altogether adequate test. Moreover, it suggests the possible presence of oil in the "Oswego lime" in the Coyote dome. Test wells should be sunk to a depth of 400 feet below the top of the "Mississippi lime" and may be located at a point 600 feet north and 1,000 feet east from the southwest corner of sec. 24, or at a point in sec. 25 about 700 feet south and 1,000 feet east from the same corner.

RODEO ANTICLINE.

Sec. 36 is crossed diagonally from southwest to northeast by the axis of a long, low anticline extending from sec. 15, T. 25 N., R. 8 E., into sec. 31, T. 26 N., R. 9 E. Only the 420-foot contour line on this fold is closed, but the accumulation of oil would be influenced by the fold throughout a much larger area than that inclosed within it. The best places for testing the Rodeo anticline are in the township to the south.[1] If producing wells are brought in there, development would naturally extend northeastward and may cover the southeast corner of sec. 35 and nearly all of sec. 36.

PRAIRIE ANTICLINE.

The tilt of the strata in the western part of the township is much more gentle than in the central and eastern parts; in fact, from the middle of sec. 7 south to the middle of sec. 31 the beds are comparatively flat-lying. The surface of the terrace thus formed is crumpled slightly, and as a result two broad, flat anticlinal folds may be distinguished. The southern of the two may be known as the Prairie anticline. Its major axis, which is crescentic in plan, extends from the center of sec. 25, T. 26 N., R. 7 E., to the southeast corner of sec. 30, T. 26 N., R. 8 E. Its closure is about 20 feet, but only 40 or 50 acres is included within the lowest closed contour line. The oil prospects of this fold can not be forecast. If suitable sands and a source of oil are present, it ought to show a fairly good yield, for the structure is adequate to bring about accumulation, but the failure of the nearest wells, those on the Disappointment dome, does not encourage too great expectation that paying sands will be found here. A good location for a test well is about 2,400 feet north of the south line and 1,500 feet east of the west line of sec. 30. This well should reach the "Mississippi lime" at a depth of about 2,500 feet and ought to penetrate it for at least 400 feet to be an adequate test.

BROWN MESA ANTICLINE.

The northern of the two major wrinkles on the surface of the terrace above referred to extends from the northwest corner of sec. 18 to the middle of the east side of sec. 19. Only one contour line on this

[1] Heald, K. C., and Mather, K. F., op. cit.

fold is closed, and it embraces only a few acres. The prospects for finding oil in this field appear similar to those of the Prairie anticline. It may be tested by drilling within the area inclosed by the 210-foot contour line in the SW. ¼ sec. 18, or near the west quarter corner of the same section.

SYNCLINES.

Synclinal areas where the structure is decidedly unfavorable to the accumulation of oil and gas are of slight extent in this township. The synclines are few, short, and narrow. The east margin of sec. 33, the west margin of sec. 34, the SW. ¼ and NE. ¼ sec. 27, and the NE. ¼ sec. 22 are particularly unpromising areas.

T. 24 N., RS. 11 AND 12 E.

By Oliver B. Hopkins and Sidney Powers.

INTRODUCTION.

The area covered by T. 24 N., Rs. 11 and 12 E., lies in the eastern part of the Osage Reservation east of Bigheart and north of Avant. (See fig. 1.) These townships were mapped entirely by plane table, in part by stadia traverse and in part by triangulation. Sidney Powers, with the assistance of G. R. Hensen, an instrument man, mapped the structure of T. 24 N., R. 12 E., and O. B. Hopkins, with the assistance, at different times, of G. R. Hensen, J. T. Richards, and H. J. Weeth, as instrument men, mapped T. 24 N., R. 11 E. The text of this report was written by Mr. Hopkins.

STRATIGRAPHY.

EXPOSED ROCKS.

The rocks exposed in these two townships comprise about 525 feet of alternating beds of shales and sandstones with beds of limestone at intervals, as shown in Plate XXXVIII. In the lower part of the section shales and limestones predominate; in the upper part, shales and sandstones. A complete description of the rocks of the area will not be given: only those beds or key rocks which were most helpful in determining the geologic structure are described. The relative position of the key beds is shown in Plate XXXVIII.

Avant limestone.—The Avant limestone, the only thick, conspicuous limestone in the area, is exposed in the lower valley of Candy Creek near the south line of T. 24 N., R. 12 E., and in the extreme northeast corner of that township. (See Pl. XXXVII.) The Avant thins from 44 feet in the vicinity of the town of Avant, near the south line of T. 24 N., R. 12 E., to 12 or 15 feet at the northeast corner of that township. The upper part of the limestone is platy and is loaded with Bryozoa and fragments of crinoid stems; the lower part is more massive and less fossiliferous. The top of this limestone was traced over the area of its outcrop shown on Plate XXXVIII.

Fusulina-bearing gray limestone.—The *Fusulina*-bearing gray limestone was traced over the greater part of T. 24 N., R. 12 E., where it is a conspicuous and valuable key bed. It crops out in the hill slope

22 feet above the southwest corner post of the township and was traced over the greater part of its area, as shown on Plate XXXVII. It is a gray to yellow thin-bedded to platy limestone from 2 to 4 feet thick. Its upper surface is covered with large *Fusulina*, which have much the shape and size of wheat grains, and its lower surface shows many *Productus* and fragments of crinoid stems. Over a large area it appears to be characterized by the presence of a species of large *Pinna*. The interval from this limestone to the Avant decreases from 115 feet in the southern part of T. 24 N., R. 12 E., to 30 feet near its northeast corner. Between the *Fusulina*-bearing limestone and the Avant there is another thin limestone (the shelly limestone of Pl. XXXVIII), but this limestone was not traced in these townships. The shelly limestone is also found in the townships to the south.[1]

Red limestone.[2]—From 8 to 20 feet above the top of the *Fusulina*-bearing limestone is the base of another limestone which because of its large content of iron usually weathers red on exposed surfaces. This limestone was traced over a considerable area in the northwestern part of T. 24 N., R. 12 E., and across the southern part of T. 24 N., R. 11 E., where it is a valuable horizon marker. (See Pl. XXXVII.) It is exposed above the *Fusulina*-bearing limestone at the southwest corner of T. 24 N., R. 12 E., and as a prominent ledge rimming the valley of Bird Creek on its north side in secs. 2, 3, and 4, T. 23 N., R. 11 E.; it is also exposed 100 feet west of the southwest corner of sec. 32, T. 24 N., R. 11 E. This limestone usually occurs in two benches, of which the lower is the more persistent and conspicuous. It is at most places a massive red or reddish-brown sandy limestone ranging from 8 to 20 feet in thickness; here and there, however, it is a purer limestone, is loaded with fossils, particularly crinoid stems, and is gray on exposed surface. In the eastern part of the area it is overlain and underlain by shale, but in the western part the shale is represented by a heavy bench of sandstone (the Clem Creek sandstone).

"*Worm-tube*" *limestone.*—Overlying the red limestone in the western part of the area is a series of massive medium-grained sandstones, with thin, lenticular beds of shale, 58 to 90 feet thick, which represent the Clem Creek sandstone. From 11 to 25 feet above the base of this series is a thin gray shaly limestone characterized by tubular markings, which probably represent remains of algae or worm tubes. This limestone is from 1 to 3 feet thick and is present in the same area in T. 24 N., R. 11 E., as the red limestone, and in

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[1] See Emery, W. B., report on T. 23 N., R. 11 E., and Tps. 22 and 23 N., R. 12 E.: U. S. Geol. Survey Bull. 686-B, p. 3, 1918.

[2] This is not the same limestone as that referred to by Winchester and others as the red limestone member of the Pawhuska limestone. See Winchester, D. E., report on T. 27 N., R. 9 E.: U. S. Geol. Survey Bull. 686-C, p. 12, 1918.

a considerable area in the western part of T. 24 N., R. 12 E., also in the northern and northeastern parts of that township, where the red limestone is absent. It was used as a key bed mainly in the northern part of T. 24 N., R. 12 E. (See Pl. XXXVII.) It is exposed, as are also the red and *Fusulina*-bearing limestones, at the southwest corner of that township; about 5 feet above a prominent sandstone bench fringed by trees near the northwest corner of sec. 3 of the same township; and in the bottom of a deep draw near the middle of the south line of the NE. ¼ sec. 13, T. 24 N., R. 11 E. The interval between this limestone and the *Fusulina*-bearing limestone increases from 36 feet at the southwest corner of T. 24 N., R. 12 E., to 59 feet in sec. 17 of that township.

Clem Creek sandstone.—Above the red limestone and including the "worm-tube" limestone is a series of massive medium-grained sandstones with thin lenticular beds of shale, 58 to 90 feet thick, which has been termed the Clem Creek sandstone.[1] The top of this sandstone is generally marked by the upper limit of the growth of trees; it is overlain by 55 to 70 feet of shale which forms a belt of open prairie country. From 5 to 10 feet above the top of the Clem Creek sandstone, which was used locally as a horizon marker, there is in places a thin bed of limestone, which weathers red on exposed surfaces. In this area the top of this sandstone does not represent a definite horizon except locally, as in different localities different ledges of sandstone form its top. The limestone above it is believed to be at about the same horizon at such widely separated points as about 300 feet northwest of the southeast corner of sec. 25, T. 24 N., R 11 E.; on top of the prominent sandstone bench about 150 feet west of the southeast corner of sec. 1 of the same township; and along the road near the middle of sec. 5, T. 23 N., R. 11 E. To the east, in T. 24 N., R. 12 E., the Clem Creek sandstone thins, and its interval is represented almost entirely by shale.

Birch Creek limestone.—Above the 55 to 70 feet of shale which overlies the Clem Creek sandstone is another series of sandstones which is substantially the equivalent of the Okesa and Torpedo sandstones of the townships to the north.[2] At the base or at some places 12 to 15 feet above the base of this series of sandstones there is a sandy limestone, named the Birch Creek limestone.[3] This limestone has been traced entirely across T. 24 N., R. 11 E., from east to west and over more than one-half of its area. (See Pl. XXXVII.) In the northeast corner of this township the limestone is absent, but a sandstone into which it grades was traced over that area. It is

[1] Emery, W. B., op. cit., p. 3.

[2] Hopkins, O. B., report on T. 25 N., Rs. 11 and 12 E.: U. S. Geol. Survey Bull. 686-H, pp. 76-77, 1918. Clark, F. R., report on T. 26 N., Rs. 10 and 11 E.: U. S. Geol. Survey Bull. 686-I, p. 95, 1918.

[3] Bowen, C. F., report on T. 24 N., R. 10 E.: U. S. Geol. Survey Bull. 686-D, pp. 17-18, 1918.

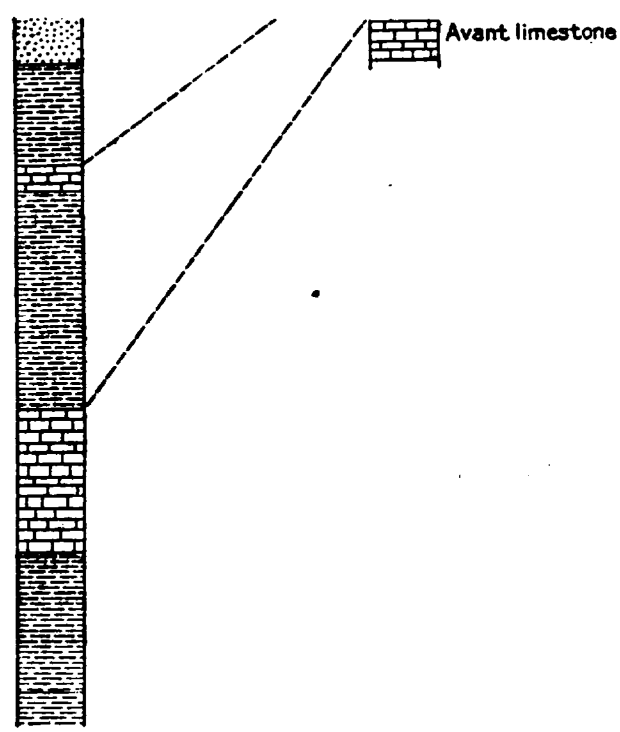
best exposed in the railroad cut 1½ miles south of Bigheart, near the east quarter corner between secs. 19 and 20; it is also exposed on the west side of Dogthresher Creek on the Avant-Bigheart road; and it rims the hollows in the NE. ¼ sec. 22, T. 24 N., R. 11 E.

The Birch Creek limestone is a hard light to dark-gray crystalline, somewhat dolomitic limestone, which contains few fossils. Its high iron content causes it to weather on exposed surfaces to a rusty-brown color. This limestone, which ranges in thickness from 4 to 11 feet, is usually sandy, at least in part, and grades laterally into sandstone. Over much of the area traced it is really a limy phase of the sandstone. The interval between this limestone and the red limestone increases from 116 feet at the southwest corner of T. 24 N., R. 11 E., to 160 feet near the southeast corner of the same township.

Okesa and Torpedo sandstones.—The Birch Creek limestone occurs at or near the base of a series of sandstones from 40 to 86 feet thick, which is substantially the equivalent of the Okesa and Torpedo sandstones farther north. The shale unit that separates these sandstones in the northern area disappears toward the south, causing the sandstones to merge so that they can not be separated easily. The top of the Okesa can be fairly definitely traced over the northern part of T. 24 N., R. 11 E., where it is ususally marked by a prominent bench with an open grassy belt formed by shale above and a rough, wooded sandstone belt below. At some places the top of the Okesa is marked by a thin but hard fine-grained even-bedded sandstone loaded with pelecypods; at other places its top is massive. It attains a maximum thickness of 86 feet in sec. 10, T. 24 N., R. 11 E.; elsewhere it ranges in thickness from 40 to 60 feet. Locally, as near the center of the W. ½ sec. 3, T. 24 N., R. 11 E., a thin limestone occurs 6 feet above the top of the sandstone.

Bigheart sandstone.—The Okesa sandstone is separated by 65 to 110 feet of shale with thin flaggy sandstones from the next massive sandstone series above, the Bigheart sandstone. This name was first applied by Snider[1] to the entire sandstone series that forms the bluffs west of Bigheart; it is here limited to the lower 40 to 70 feet of massive beds of this sandstone series. This sandstone forms a prominent escarpment along the north half of the west side of T. 24 N., R. 11 E., and caps the high hills in the northern part of that township. (See Pl. XXXVII.) The basal bed is coarse grained to conglomeratic along the west line of that township but grades into medium-grained sandstone toward the northeast. The base of this sandstone or the top of its lowest prominent bench was traced over the area outlined on Plate XXXVII.

[1] Snider, L. C., Preliminary report on the clays and clay industry of Oklahoma: Oklahoma Geol. Survey Bull. 7, p. 221, 1911.



COLUMNAR SECTIONS OF ROCKS EXPOSED IN T. 24 N., RS. 11 AND 12 E.

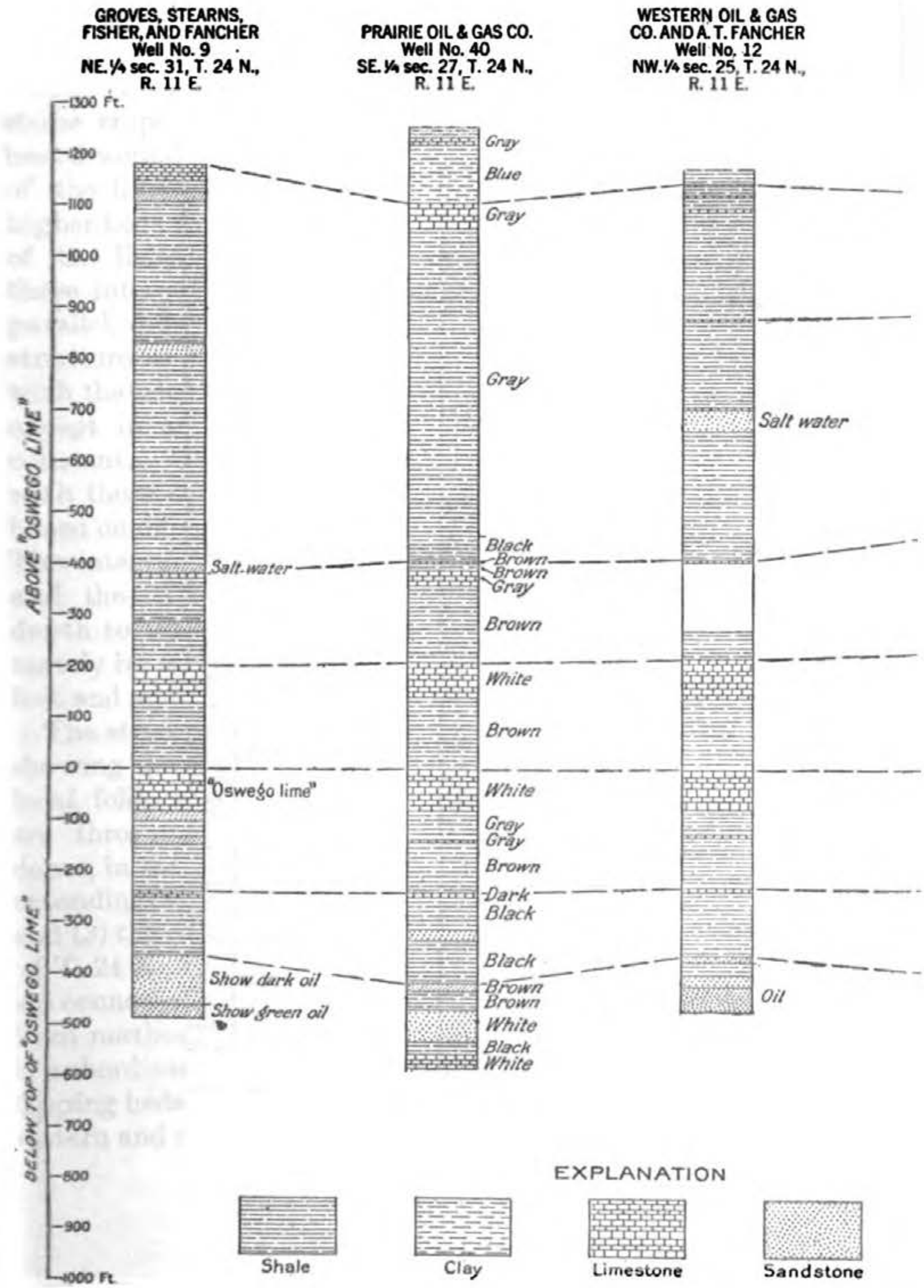
Sands at this horizon underlie these townships and have made prominent showings of gas at many places, notably in the NE. ¼ sec. 7 and the NW. ¼ sec. 8, T. 24 N., R. 12 E.

Bartlesville sand.—Under the name Bartlesville sand is included a group of lenticular beds of sand ranging from 25 to 150 feet in thickness, which lie from 350 to 450 feet below the top of the "Oswego lime," or 1,550 to 1,725 feet below the surface in this area. The Bartlesville has yielded at least 99 per cent of all the oil so far produced in this area and probably an equal percentage of gas.

The upper part of the Bartlesville is commonly gas bearing, and in many places it is separated from the main oil-bearing beds below by a thin bed of black shale. This upper sand is commonly referred to by the driller as "barren." The best yield of oil is usually found from 50 to 100 feet below the top of the sand. The Bartlesville has been reached by more than 1,100 wells in this area. So far as known it is recorded in the logs of practically all these wells, although its thickness and porosity vary from place to place, causing local variations in the yield of the wells.

Burgess sand.—The sand which in places lies immediately on top of the "Mississippi lime" is called by the drillers the Burgess sand. This sand is shown in two logs in Plate XXXIX. It is not known whether any oil wells have been finished in this sand, as many of the logs are not available and many are too incomplete to permit the identification of the sand; at least one small gas well has been completed in it. It is safe to say that this sand has been reached in relatively few of the wells, and that it is untested in a large part of the area.

"*Mississippi lime.*"—The limestone reached in the wells in this area at a depth of 1,750 to 1,900 feet is commonly called the "Mississippi lime." The age of this limestone is not definitely known, but it is believed to be the equivalent of the Boone limestone of the Kansas-Oklahoma section. This limestone has been reached in at least 15 wells in this area and it has been penetrated in at least one. (See Pl. XXXIX.) The log of the Wolverine Oil Co.'s well No. 69, in the NW. ¼ sec. 19, T. 24 N., R. 12 E., shows this limestone to be 249 feet thick and to be underlain by almost 200 feet of sand. This limestone is an important gas-bearing formation in different parts of Osage County, and it probably contains gas in some of the areas of favorable structure in these townships. Before a hole is abandoned as dry it should be drilled through this lime into the underlying sand, unless near-by wells have adequately tested these formations.


GROVES, STEARNS, FISHER, AND FANCHER
Well No. 9
NE. 1/4 sec. 31, T. 24 N., R. 11 E.
PRAIRIE OIL & GAS CO.
Well No. 40
SE. 1/4 sec. 27, T. 24 N., R. 11 E.
WESTERN OIL & GAS CO. AND A. T. FANCHER
Well No. 12
NW. 1/4 sec. 25, T. 24 N., R. 11 E.
1300 Ft.
ABOVE "OSWEGO LIME"
BELOW TOP OF "OSWEGO LIME"
1000 Ft.
Gray
Blue
Gray
Gray
Salt water
Black
Brown
Brown
Gray
Salt water
Brown
White
Brown
"Oswego lime"
White
Gray
Gray
Brown
Dark
Black
Black
Show dark oil
Brown
Brown
Show green oil
White
Black
White
Oil
EXPLANATION
Shale
Clay
Limestone
Sandstone

SECT

STRUCTURE.

GENERAL FEATURES.

The structure of this area is shown on Plate XXXVII by means of contours based on a theoretical datum 370 feet above the top of the *Fusulina*-bearing gray limestone. In the area in which this limestone crops out the datum elevations on which the contours are based were determined by adding 370 feet to the elevation of the top of the limestone; in most places where the limestone was absent higher beds were traced and elevations on them were reduced to that of the limestone by subtracting the interval between them. As these intervals are not constant, because the beds are not exactly parallel, different intervals were used in different places, causing the structure as shown on Plate XXXVII to disagree in minor details with that determined from elevations based on a locally traced bed, except in areas where the intervals have been found to remain constant. The contours drawn for this area do not agree exactly with those drawn for the townships to the south, because they are based on different datum beds which are only approximately parallel. The interval between the datum on which the contours are drawn and the "Oswego lime" ranges from 1,440 to 1,480 feet. The depth to the "Oswego" at any point may be determined approximately by subtracting the contour elevation at that point from 1,460 feet and adding the elevation of the surface.

The structure of this area conforms broadly to that of the region, showing the generally westward dip interrupted here and there by local folds and faults. The major structural features of the area are three strongly developed anticlines or domes—(1) the Gypsy dome, in sec. 32, T. 24 N., R. 12 E.; (2) the Eleven-twelve anticline, extending from sec. 18, T. 24 N., R. 12 E., into sec. 12, T. 24 N., R. 11 E.; and (3) the very steep-sided Birch Creek dome, in the southwest corner of T. 24 N., R. 11 E. The Gypsy dome and Eleven-twelve anticline are connected by a low saddle. A belt of relatively steep dips extends from northeast to southwest across T. 24 N., R. 11 E., and a number of subordinate anticlines and synclines are seen in the areas of gently dipping beds in the eastern part of T. 24 N., R. 12 E., and the southeastern and northwestern parts of T. 24 N., R. 11 E.

AREAS OF FAVORABLE STRUCTURE.

BIRCH CREEK DOME.

The Birch Creek dome lies mainly in secs. 29, 30, 31, and 32, T. 24 N., R. 11 E., but extends into the adjoining township on the west.[1] It is an oval dome with steep dips on all sides and curved

[1] Bowen, C. F., report on T. 24 N., R. 10 E.: U. S. Geol. Survey Bull. 686-D, pp. 21-22, 1918.

axis. This axis extends from a point near the center of the NW. ¼ sec. 31 northeastward to a point one-eighth of a mile north of the northeast corner of that section, where it bends to the east; farther on it turns slightly south of east and continues to the south line of sec. 29. The area of closure, outlined by the 1,080-foot contour, includes considerably more than two sections, and the reversal in dip amounts to about 120 feet. The beds on all sides of this dome have abnormally strong dips for this region but the dip is steepest on the northwest side, where it amounts to as much as 270 feet to the mile, or approximately 3°. This dome is separated from the Minnehoma dome, on the east, by a narrow syncline.

This large dome with steep dips on all flanks furnishing an extensive gathering ground, affords exceptionally favorable structural conditions for oil accumulation. Oil has been obtained at many places on its north and northeast slopes and gas along its crest, particularly near its east end. One of the largest wells in the Osage Reservation, reported to have had an initial daily production of 3,100 barrels, was drilled on the north slope of this dome. The initial production of the wells in sec. 29 varies widely, suggesting that there is considerable local variation in the porosity of the sand. The chances of finding oil on the northwest and west slopes of this dome, in secs. 30 and 31, are good, notwithstanding the presence of several dry holes there. All the promising area on this dome has been leased, and future drilling will soon define the limits of this pool. The dry hole in the NW. ¼ sec. 30 penetrated 82 feet of Bartlesville sand and was abandoned 32 feet below the top of the "Mississippi lime." This hole is in the bottom of a syncline and is therefore unfavorably located structurally. The dry hole in the SE. ¼ sec. 30 was drilled 360 feet into the "Mississippi lime" and did not encounter any sand at the horizon of the Bartlesville; this seems strange, because almost 100 feet of the Bartlesville was reported in the log of the well drilled in the NE. ¼ sec. 31.

LABARDIE DOME.

The Labardie dome [1] is a relatively small fold whose crest is near the middle of the line between secs. 3 and 4, T. 23 N., R. 11 E. It is cut in sec. 4 by a fault which has a maximum downthrow on its northeast side of about 50 feet in sec. 33, T. 24 N., R. 11 E., and which extends northwestward across Birch Creek and probably joins with one on the eastern flank of the Birch Creek anticline. The Labardie dome has a closure of 30 feet and a closed area of about 600 acres as outlined by the 1,100-foot contour. A dry hole has been drilled on the crest of this dome, but it is not known whether

[1] Emery, W. B., report on T. 23 N., R. 11 E., and Tps. 22 and 23 N., R. 12 E.: U. S. Geol. Survey Bull. 686-B, p. 8, 1918.

this hole is an adequate test, as its record is not available. This dome is small, however, and does not offer particularly favorable conditions for the accumulation of oil, because of its relatively small gathering ground.

The Labardie dome is connected by a shallow saddle with a smaller dome, whose crest is near the northeast corner of sec. 3, T. 23 N., R. 11 E. This dome has a reversal of dip of about 20 feet and an area of closure of approximately 175 acres, outlined by the 1,100-foot contour. No wells have been drilled on this dome, which is considered worthy of a test. A good location for a test would be in the SE. ¼ SE. ¼ sec. 34, T. 24 N., R. 11 E.

MINNEHOMA DOME.

The Minnehoma dome is situated in secs. 27, 28, 33, and 34, T. 24 N., R. 11 E., covering an area of about two sections. It is an irregularly shaped dome, its symmetry being destroyed by two faults which cut it, and by relatively steep dips to the north and west and gentle dips to the south and east. It is limited on the west by a pronounced syncline, which separates it from the Birch Creek dome, and on the east by a broad, shallow syncline. This dome is cut by a northwestward-trending fault which appears to be continuous with that observed on the opposite side of Dogthresher Creek, where it has a maximum throw of approximately 50 feet. The upthrow is on the southwest side of the fault. It is difficult to contour accurately the beds at the southeast end of the fault, as they appear to have been dislocated by slumping as well as by faulting. Another fault trending N. 75° W. cuts across the southwest corner of sec. 27. It has a maximum throw of 15 feet, with the upthrow on the north side.

Oil has been obtained in numerous wells on the north and northwest slopes of this dome in sec. 27. If the large fault referred to above offsets the oil-bearing sand so that oil can not migrate from one side of it to the other, oil may not be found in large quantities on the west slope of the Minnehoma dome, as the oil which would normally have collected there appears to have been trapped in the saddle between this dome and the Birch Creek dome. Only one failure on the west slope of the dome has been recorded, and this slope can not yet be considered fully tested. If oil is not found near the crest of this dome in the SE. ¼ sec. 28 and the NE. ¼ sec. 33, gas will probably be found.

BIGHEART ANTICLINE.

Because of the wide belt of alluvium east of Bigheart the structure in that vicinity is difficult to determine. The structure contours on Plate XXXVII, which are believed to be essentially correct, indicate that there is a low anticline, extending almost due north from the NE. ¼ sec. 19 to Bigheart, where it bends sharply to the east. The crest of this anticline, as outlined, follows closely the Midland Valley Railroad south of Bigheart and the south line of secs. 7 and 8 east of the town. In reality this is not a true anticline but a much elongated anticlinal nose, without closure, leading westward from the Dogthresher dome.

The anticline is cut near Bigheart by a northwesterly fault that has a downthrow locally of about 60 feet on its northeast side. A northward extension of this fold appears to connect it with the Redeagle anticline, in the township to the west.[1]

Oil has been obtained on the northwest slope of this anticline just west and northwest of Bigheart. The oil is derived from the Bartlesville sand, and the wells range in initial daily production from 8 to 800 barrels. Two wells having an initial capacity of 10 and 13 barrels were drilled on the eastern part of this anticline in the NE. ¼ sec. 17. It seems probable, from a consideration of the structure and the present development, that small wells can be drilled along the crest of this fold east and probably south of Bigheart. Drilling away from the productive areas should be continued until the commercial limits of the pool are clearly defined.

DOGTHRESHER DOME.

The Dogthresher dome, so named from the creek which crosses it, lies 2 miles east of Bigheart, largely in secs. 15 and 16 but extending into the sections which border these on the north and south. This low, flat, oval dome, outlined by a single closed contour, the 980-foot contour, has an area of closure of about 150 acres, mainly in the NE. ¼ sec. 16. This area of closure is near the middle of a broad structural flat or terrace which covers the greater part of secs. 15 and 16, the southeast corner of sec. 9, and the southern part of sec. 10.

Oil has been obtained at many places on this dome, as shown on Plate XXXVII, from which it will be seen that the productive area is practically continuous toward the south with that on the Minnehoma and Bird Creek domes. The wells range in initial daily production from a few barrels up to 600 barrels, but most of them range from 25 to 100 barrels. The belt in which the largest wells have been developed extends from about the center of the NE. ¼ sec. 21 north-northeastward past the northeast corner of sec. 16 to the middle of sec. 10. All the favorable territory on this dome has been leased, and the drilling that is now under way will soon limit the area over which this pool is commercially productive. To judge

[1] Bowen, C. F., report on T. 24 N., R. 10 E.: U. S. Geol. Survey Bull. 686–D, pp. 22, 23, 1918.

from the structure and the initial production of the wells, there is a considerable belt on all sides of the present producing area in which wells can be drilled that will have an initial production of 5 to 15 barrels a day.

MANHATTAN DOME.

The Manhattan dome lies mainly in the SW. ¼ sec. 24 and the NW. ¼ sec. 25, T. 24 N., R. 11 E., but extends into the adjoining sections on the west. It is a low roughly circular dome with a closure of about 20 feet. It has an area of closure of not more than a quarter section, outlined by the 1,120-foot contour. This dome is at the upper edge of a wide belt in which the beds have an abnormally steep dip. The beds to the north and especially to the south of this dome are relatively flat over a large area. This area of relatively flat beds, because of its position near the upper edge of the belt of steeply dipping beds, affords conditions favorable for oil accumulation beyond the limits of the dome. The Manhattan dome, together with the Eleven-twelve anticline, to the north, the Gypsy dome, to the east, and the saddle which connects them, gives rise to the accumulation of probably the largest developed oil pool in the Osage region.

To judge from the structure and the wells that have been drilled the chance is good of further extending the pool from a quarter to half a mile along its western edge by wells with an initial daily production of 5 to 20 barrels. It is probable that wells of small yield may be obtained over the greater part of sec. 36. An attempt should be made to extend the pool to the southwest along the anticlinal axis which crosses sec. 35 diagonally from its northeast to its southwest corner. All the oil in the area comes from the Bartlesville sand. The wells range in initial daily production from 10 to 400 barrels, but most of them produce initially from 10 to 75 barrels.

ELEVEN-TWELVE ANTICLINE.

The Eleven-twelve anticline, so named because half of it is in R. 11 E. and half in R. 12 E., covers most of secs. 12 and 13, T. 24 N., R. 11 E., and secs. 7 and 18, T. 24 N., R. 12 E. It is a strongly developed fold about three times as long as it is broad. Its axis extends southeastward from a point near the center of the S. ½ sec. 12, T. 24 N., R. 11 E., to the middle of the south line of sec. 18, T. 24 N., R. 12 E., beyond which it is connected by a broad saddle with a nose of the Gypsy dome. The dips are steep on the west, north, and northeast sides of this anticline but fairly gentle on its south and southeast sides. The area of closure, as outlined by the 1,160-foot contour, consists of about one section, or 640 acres. The reversal of dip is approximately 50 feet.

The strong dips which prevail over a wide belt on the west side of this anticline, amounting to 210 feet within a distance of 2 miles, and also the strong dips on its north and northeast sides, amounting to 130 feet within less than 2 miles, make the structural position of this anticline particularly favorable for large accumulations of oil and gas. Six gas wells have been drilled on the crest of this fold and on its southwest slope, and a large number of oil wells have been drilled on its southwestern, southern, and eastern slopes. The logs of the three gas wells in sec. 12, T. 24 N., R. 11 E., are not available, and it is not known how deep they were drilled or from what horizon their gas is produced. The gas wells in sec. 13 of the same township appear to yield gas from the Bartlesville sand. So far as is known, all the oil wells are producing from the Bartlesville. Well No. 69 of the Wolverine Oil Co., in the NW. ¼ sec. 19, T. 24 N., R. 12 E. (see plotted section of this well on Pl. XXXIX), was drilled to the depth of 2,190 feet; it penetrated the "Mississippi lime" and drilled through 195 feet of water-bearing sand below it.

Most of the wells thus far drilled on this anticline range in initial daily production from 10 to 50 barrels; one well, however, yielded 1,000 barrels, another 600 barrels, and still another 500 barrels. The small initial production of most of the wells is due to the thinness and fineness of the pores of the Bartlesville sand, which ranges in thickness from 25 to 80 feet, but in most wells is less than 40 feet thick.

Notwithstanding the relative thinness of the Bartlesville sand and the presence of three dry holes, the chances of extending the productive area on this anticline are good, especially on its western and northern slopes. One dry hole near the center of sec. 14, which was drilled to about the top of the "Mississippi lime," is too far down the dip to be productive; the one in the northeast corner of the same section has no available record and its depth is not known; the third one, in the SW. ¼ NW. ¼ sec. 13, was drilled to a depth of 2,059 feet, probably through the "Mississippi lime," and although it encountered some Bartlesville sand, it was not commercially productive. Drilling should be continued in an effort to extend the pool over the southern and western parts of sec. 13 and over those parts of sec. 12, T. 24 N., R. 11 E., and sec. 7, T. 24 N., R. 12 E., lying between the 1,100 and 1,150 foot contours. Above the 1,150-foot contour gas is likely to be found unless it has been exhausted by the gas wells already drilled.

GYPSY DOME.

The crest of the Gypsy dome is slightly north of the center of sec. 32, T. 24 N., R. 12 E. This is an oval dome with steep dips on its west side and gentle dips on its north, east, and south sides. It has an area of closure, as outlined by the 1,220-foot contour, of approximately 240 acres and a reversal of dip of about 30 feet. The doming, however, affects an area three to four times as large, covering almost all of sec. 31, the southern part of sec. 29, and parts of the sections bordering these on the east. A nose projecting from this dome to the northwest connects it with the Eleven-twelve anticline.

Oil has been obtained in many places on the southern, western, and northern flanks of this dome. The area of oil development on it merges with that on the Eleven-twelve anticline and on the Manhattan dome, forming a single extensive pool. No well has yet been drilled on the crest of this dome; the one nearest the crest is on its southwestern slope and is a dry hole. Two others near the crest but on its eastern slope were also dry. The largest wells in this pool were drilled on the western flank of the Gypsy dome in a narrow belt between the center of the W. ½ sec. 32 and the center of sec. 31. Over a small area in that belt the wells produced initially from 100 to 2,400 barrels a day. On the northwestern flank, in an area as favorably located structurally, the wells produced from 20 to 100 barrels. This difference in initial production is probably due to differences in the porosity or thickness of the productive sand.

The chances are not especially good for an extensive development of this pool, as the surrounding area has been well tested. However, it seems likely that the productive area may be extended somewhat by the drilling of wells, which will probably be small producers, over much of the undeveloped parts of secs. 29 and 32.

OTHER AREAS OF FAVORABLE STRUCTURE.

An anticlinal nose extends from the SW. ¼ sec. 9 to the NW. ¼ sec. 8, T. 24 N., R. 12 E., and is roughly outlined by the 1,140-foot contour. The beds are flat over a considerable area in the southwestern part of sec. 9 and the southeastern part of sec. 8, except in a small area of gentle doming in sec. 8, outlined by a closed 1,150-foot contour. Oil has been obtained on this nose in both the Peru and Bartlesville sands near the southeast corner of sec. 8 and in the Bartlesville farther northwest, on the end of the nose. The wells in this area produced initially 5 to 125 barrels a day, and so far no favorably located well has been unproductive. To judge from the structure and the production of the wells, the productive area may be extended over practically all of sec. 8 except the N. ½ N. ½ and probably over a considerable part of the W. ½ sec. 9.

Along the eastern boundary of the Osage Reservation in T. 24 N., R. 12 E., there is evidence of anticlinal folding at two places, but as the mapping was not carried beyond the limits of the reservation, these folds are not outlined in their entirety. From the 1,230-foot contour in sec. 10, which is near the edge of the area mapped, the beds dip to the north, west, and south, suggesting the presence of a fold here. This area in sec. 10 is undoubtedly anticlinal, as shown by the swing of the contours around it to the north and south. Extensive drilling in this section, however, resulted in only a few producing wells, which are now abandoned.

In sec. 22 there is a broad flat, outlined by the 1,200-foot contour, and within it a small area of gentle doming, outlined by the 1,210-foot contour. Considerable oil has been obtained on this flat and even beyond its limits to the north and south. In fact, the presence of the pool of oil which extends from the south line of the township northward along the reservation boundary can not be adequately explained on the basis of the surface structure as mapped. It would seem that the productive area here is controlled largely by the character of the sand, or by folding in the sand which is not reflected in the surface beds.

AREAS OF UNFAVORABLE STRUCTURE.

Oil is usually found in the Osage Reservation associated with anticlines, terraces, or structural noses, and most abundantly on the west or northwest sides of these features; it is seldom found in commercial quantities in major synclines or in areas of featureless, normal west dip. A study of Plate XL will show that in this area the oil pools are associated with anticlinal folds, although some of them extend beyond the limits of individual folds across synclinal areas and unite with pools on other folds, as in the syncline between the Birch Creek and Minnehoma domes. In at least one pool of oil, the one lying along the eastern edge of the reservation in T. 24 N., R. 12 E., the surface structure does not adequately account for the accumulation, which seems to be controlled rather by the thickness and porosity of the productive sand. Wherever the productive sand is uniform in thickness and porosity in this area the structure is believed to be the controlling feature in the accumulation of oil, and oil should generally be looked for only in areas of favorable structure; however, as the productive sand varies much in thickness and porosity, oil may be found in areas of unfavorable structure if the sand conditions are favorable. Oil is least likely to occur in commercial quantities in major synclines, even under favorable sand conditions.

Major synclines occur in sec. 6, T. 23 N., R. 11 E., as outlined by the 1,030-foot contour and in secs. 5 and 6, T. 24 N., R. 11 E., as outlined by 910-foot contour. One extends from the southwest corner of sec. 19, T. 24 N., R. 11 E., northeastward and northward into the NE. ¼ sec. 17; and another extends from a point near the center of sec. 2, T. 24 N., R. 11 E., east-northeastward and eastward, through the northern part of sec. 6, T. 24 N., R. 12 E., from which one branch turns southward through sec. 7 and southeastward across sec. 17 into sec. 20, where its southern extension becomes less pronounced. It is likely that oil will be found in commercial quantities in the area of steep dips below the 1,060-foot contour between sec. 23 and sec. 11, T. 24 N., R. 11 E., or below the 1,010-foot contour in sec. 3 of the same township.

RELATION BETWEEN SURFACE STRUCTURE, UNDERGROUND STRUCTURE, AND PRODUCTION.

To show some differences between the structure of the exposed rocks and that of the deeper strata and to illustrate the productivity of different parts of the folds, a part of the area described in this chapter is specially mapped in Plate XL. In this map, which covers the southeast corner of T. 24 N., R. 11 E., and the southwest corner of T. 24 N., R. 12 E., are shown structure contours based on (1) the surface beds, (2) the top of the "Oswego lime," and (3) the top of the oil sand (Bartlesville). The contouring of the underground structure is based on well logs, many of which are old and not absolutely reliable; however, the area in which the underground structure is contoured is thoroughly drilled, and so many data are available that the major features are believed to be correctly shown.

A consideration of this plate shows a fairly close resemblance between the surface structure and the structure of the "Oswego lime," in the southwest corner of T. 24 N., R. 11 E. The anticline in the northwest corner of sec. 25 is indicated by the same two sets of contours, as are also the nose extending southwestward past the northeast corner of sec. 35 and the parallel syncline in the northwestern part of sec. 36, though these features are more pronounced in the "Oswego" than in the surface beds. In the southwest corner of T. 24 N., R. 12 E., this similarity of the structure at these two levels is less apparent; a narrow, sharp syncline in the "Oswego" extends from the southwest corner of sec. 30 to and beyond the northeast corner, crossing a belt in which the surface rocks dip gently to the west.

A comparison of the structure of the Bartlesville sand with that of the surface beds and the "Oswego lime" reveals more striking differences. In the southeast corner of T. 24 N., R. 11 E., the contours based on the oil sand (more precisely the top of the productive bed of sand or the top of the oil surface) show a slight similarity to those based on the other data, but in the southwest corner of T. 24 N., R. 12 E., there is no similarity whatever. In secs. 30 and 31, where the surface beds and the "Oswego" dip steeply to the west, the oil sand is essentially flat. This may indicate either that the Bartlesville does not conform to the structure in the overlying beds in that area or, what is more likely, that the top surface of the oil is not parallel to the top of the sand, possibly because the oil occurs in more or less closely connected lenses of sand lying at different horizons. Sufficient work has not been done to explain why the oil surface is essentially horizontal where the overlying beds dip steeply.

In the southeast corner of T. 24 N., R. 11 E. (see Pl. XL), the areas of large initial production are chiefly in the areas of most favorable structure. This is also true of the Dogthresher dome. In the southwest corner of T. 24 N., R. 12 E., the areas of large initial production are more irregular than in the township to the west, and they do not conform so well to the areas of favorable structure. The variation in the initial production in secs. 29, 30, 31, and 32, as shown on Plate XL, is believed to be due to local variations in the thickness or more probably in the porosity of the sand. As the Bartlesville sand is a shore or near-shore deposit, it was laid down irregularly and its beds vary widely from place to place in texture, and consequently in the size of the pore spaces. This variation may have been increased by subsequent cementation.

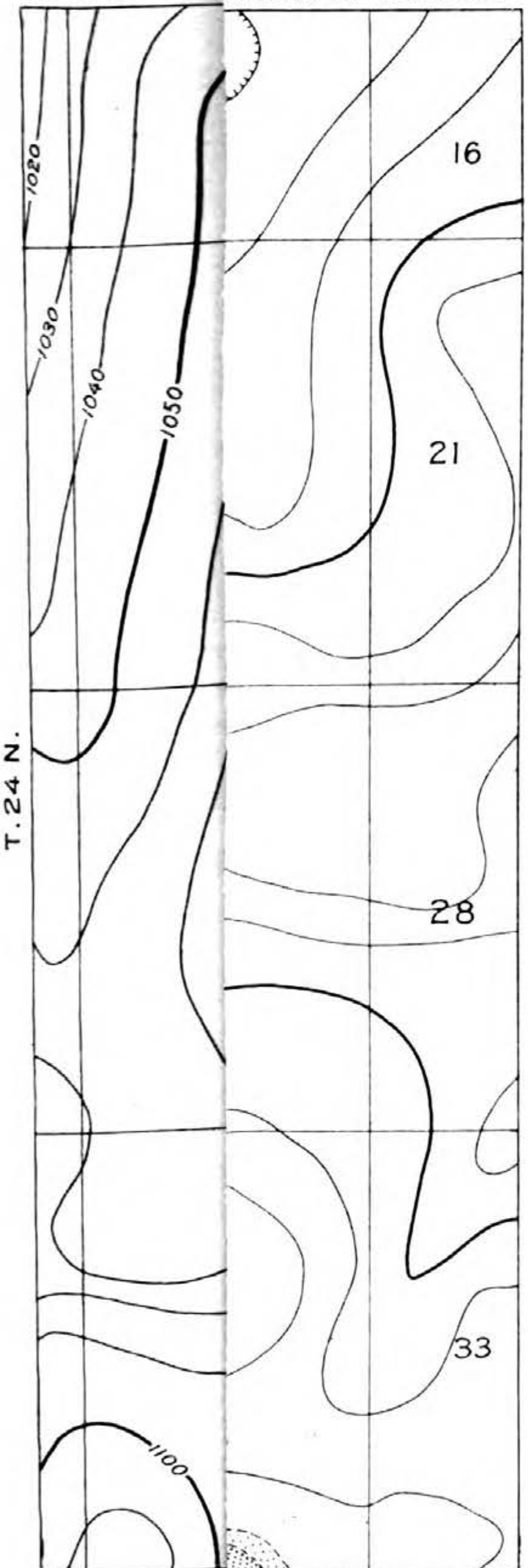
PRODUCTION.

A study of the record of the initial daily production of 519 wells in these townships showed that six wells had a production of 1,000 barrels or over and one had the maximum production of 3,600 barrels. One well in T. 24 N., R. 11 E., produced 3,100 barrels a day; the available records of 289 other wells in this township showed an average initial daily production of 85 barrels.

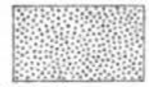
Initial daily production of 289 wells in T. 24 N., R. 11 E.

Production in barrels.	Number of wells.	Percentage of total wells.
0-25	97	33.6
26-50	75	26.0
51-75	29	10.0
76-100	27	9.4
101-200	32	11.0
201-300	15	5.2
301-400	4	1.4
401-500	7	2.4
501 or more	3	1.0
	289	100.0

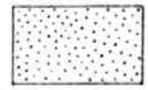
Of 229 wells in T. 24 N., R. 12 E., five showed an initial daily production of 1,000 barrels or more; the average production of the remaining 224 wells was 93.1 barrels.



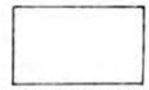
EXPLANATION



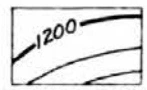
Initial daily production 101 barrels or more



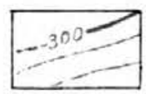
Initial daily production 50-100 barrels



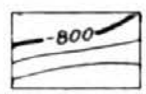
Initial daily production less than 50 barrels



Structure contours drawn on a theoretical bed 370 feet above top of *Fusulina*-bearing gray limestone



Structure contours on top of "Oswego lime"



Structure contours on top of oil-bearing bed in Bartlesville sand

Contour interval 10 feet
Datum is mean sea level

HOMA

Initial daily production of 224 wells in T. 24 N., R. 12 E.

Production in barrels.	Number of wells.	Percentage of total wells.
0–25	62	27.7
26–50	55	24.5
51–75	22	9.8
76–100	32	14.3
101–200	34	15.2
201–300	8	3.6
301–400	4	1.8
401–500	1	.4
501 or more	6	2.7
	224	100.0

In general the areas in which the wells have the greatest initial production are within those that show favorable structure in the surface rocks, but the distribution of the most productive areas within the areas of favorable structure is dependent on the porosity and thickness of the sand. The position of the belts in which the wells have large initial production is dependent on the thickness, porosity, and extent of beds of sand, and they do not, as a rule, correspond in trend to the folds. It therefore follows that the areas of maximum production do not conform in all respects to the structural features, and a lease on the flank of a fold may be more valuable than one whose location is structurally more favorable.

T. 27 N., R. 11 E.

By Heath M. Robinson and R. V. A. Mills.

INTRODUCTION.

T. 27 N., R. 11 E., is in the northeastern part of the Osage Reservation, as shown in figure 1. The southeast corner of the township is about 5 miles by road from the town of Bartlesville, which is on both the Atchison, Topeka & Santa Fe Railway and the Missouri, Kansas & Texas Railway. Owing to the hauling of heavy loads from Bartlesville to the oil fields in this vicinity the roads are rough, but they are constantly being used by automobiles, motor trucks, and other vehicles. Water for use in drilling is supplied by Buck Creek, Butler Creek, and a number of ponds in which surface water is collected. Except for the country near Buck and Butler creeks the township for the most part is unwooded, which makes it possible to do rapid and efficient plane-table work.

The field work on which this report is based was done by Heath M. Robinson, R. V. A. Mills, Frank Reeves, and Frank R. Clark, geologists, assisted by Lewis Mosburg, instrument man. The area mapped by each geologist is shown by the diagram inserted on Plate XLI. The plane table and telescopic alidade were used in mapping the structure, and the elevations were controlled by a system of triangulation which was checked within itself and with the Government bench marks in this township. All the office work on this report was done by Heath M. Robinson, who is responsible for the statements and conclusions herein presented.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL CHARACTER.

The rocks exposed in T. 27 N., R. 11 E., are of middle Pennsylvanian age and comprise about 425 feet of shale, sandstone, and limestone. Shale constitutes the greater part of the section, sandstone a large part, and limestone a very minor part. The limestones, however, are very excellent key beds and consequently were found to be of value in determining the structure of the township.

The character and succession of the exposed rocks are shown graphically in figure 41, which shows also their relation to the stratigraphic section exposed in the northern part of the Osage Reservation. The data for the section exposed in the northern part of the Osage Reservation were compiled from United States Geological Survey Bulletins 641-B, 691-C, 686-F, and from the field notes on T. 27 N., R. 11 E. The relation between the exposed and the subsurface beds in T. 27 N., R. 11 E., is graphically shown on Plate XLII.

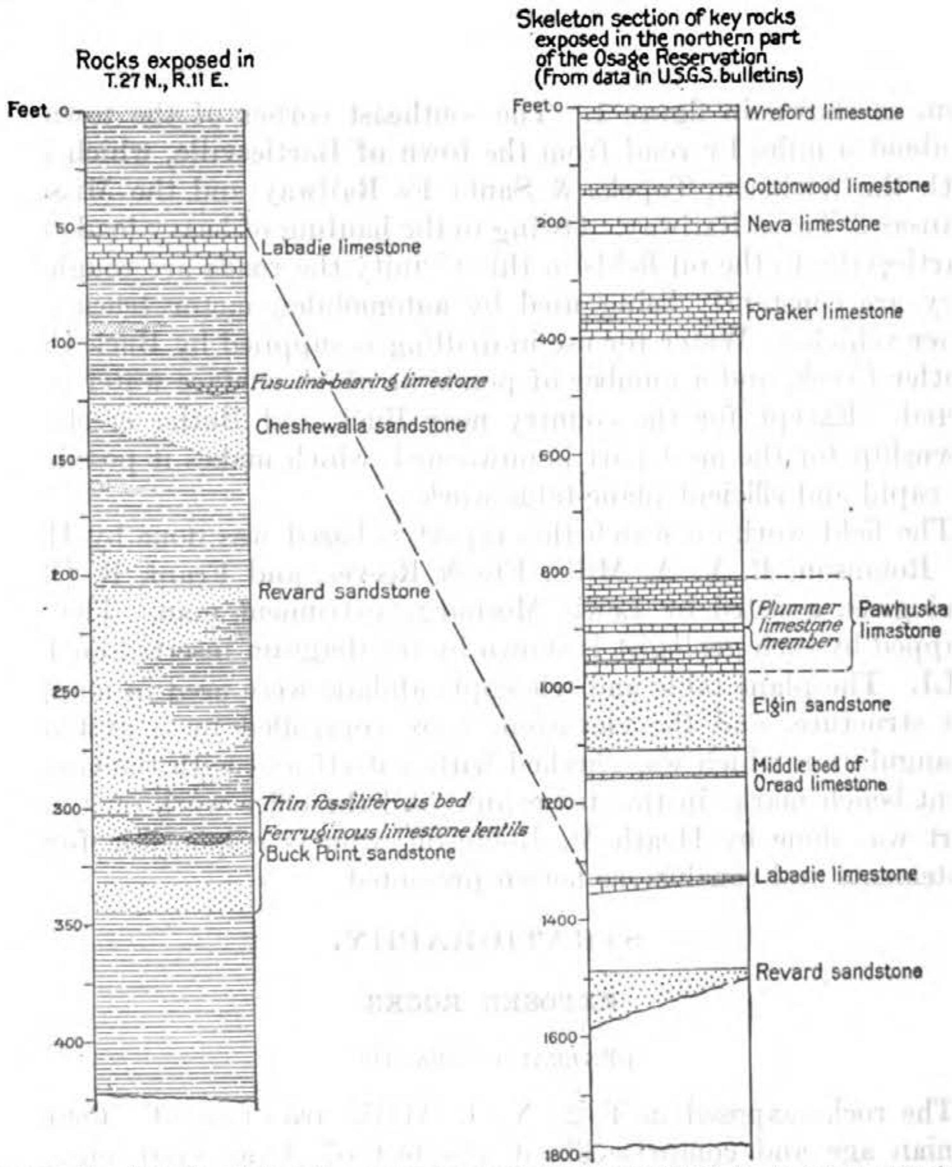


FIGURE 41.—Stratigraphic sections showing rocks exposed in T. 27 N., R. 11 E., and their relation to the section exposed in the northern part of the Osage Reservation.

As this report is strictly economic no attempt is made to give a detailed description of the stratigraphy of the region. However, it is believed that a description of those beds which were found to be useful in mapping the structure will be serviceable to other geologists who may do geologic work in this township after the publication of this report, and hence these key beds are here briefly described.

KEY BEDS.

Labadie limestone.—The outcrop of the Labadie limestone is shown on Plate XLI, and its position with respect to other beds in the township is shown in figure 41. The average thickness of this limestone is about 20 feet, and in this township it does not vary more than 2 or 3 feet from this average. However, a mile or so north of the northern boundary of the township the limestone is much thinner, ranging from less than a foot to 3 or 4 feet in thickness. The main body of the limestone is gray, but in some outcrops the upper part is colored a rich cinnamon-brown. The limestone is not densely fossiliferous, but in most of the outcrops a few scattered fossils may be found. It is more resistant to weathering than the associated shales; consequently it forms the cap rock of many of the small hills in the northwestern part of the township. It commonly weathers into roughly rectangular slablike masses an inch or so thick and 2 or 3 feet in their greatest dimension. In this township its outcrop is free from trees, and because it is in general prominently exposed it makes a very satisfactory bed to use for mapping the structure.

Fusulina-bearing limestone.—The outcrop of the *Fusulina*-bearing limestone is not shown on Plate XLI, but its position in the stratigraphic section is shown in figure 41. As indicated there, it is lenticular, and apparently its outcrop is confined to a few scattered localities in the northern part of the township. It ranges from a few inches to 3 or 4 feet in thickness, is gray on freshly fractured surfaces, and is practically made up of long, slender *Fusulina.* Its outcrop is usually inconspicuous, but because of its marked characteristics and its definite position in the section it was found to be a useful key bed in mapping the structure in this township.

Cheshewalla sandstone.—As shown in figure 41, the Cheshewalla sandstone lies almost directly beneath the *Fusulina*-bearing limestone, described above. Where this limestone was absent the top of the Cheshewalla sandstone was found to serve as a very good substitute in mapping the structure, for the bed was found to be persistent and the outcrop fairly distinct. The sandstone is dark gray on weathered surfaces and is from 5 to 25 feet thick. It is massive and in character has little to distinguish it from other massive sandstones found in the township.

Revard sandstone.—The outcrop of the top of the Revard sandstone is shown on Plate XLI, and its stratigraphic position is shown in figure 41. This sandstone is as thick as 100 feet in the southwest corner of this township, but in many other localities in the township it measures between 5 and 40 feet. The top of the sandstone was found to be fairly persistent, and the contact between the overlying predominantly shale series, which generally was unwooded, with this predominantly sandstone series, generally wooded, furnished the most usable datum available for mapping the structure over a good part of the township. The sandstone is massive and cross-bedded and, like the Cheshewalla, has few characteristics to distinguish it from other similar massive sandstones that outcrop in the township.

Thin fossiliferous bed in the Buck Point sandstone.—About 93 feet below the top of the Revard sandstone in the southeastern part of T. 27 N., R. 11 E., is a bed of sandstone which is 1 or 2 feet thick, dark gray on weathered surfaces, and richly fossiliferous. The fossils belong to the genus *Productus* and are large and round. The sandstone weathers into blocks several feet across, and the weathered surface is usually found to have a liberal sprinkling of these fossils, which appear as rounded bumps raised about half an inch above the surface of the sandstone. As the bed is thin, consequently marking a very definite horizon, and as it is easily recognizable in the field, it was found to be very useful in mapping the structure of part of this township.

The outcrop of this bed is shown on Plate XLI and its relation to the other beds found in this township is graphically shown in figure 41. The development of the Buck Point sandstone in T. 26 N., R. 11 E., the township just south of this one, has been described by Frank R. Clark.[1]

Between 8 and 15 feet below the fossiliferous bed described above there crops out in a few scattered localities in this township a dark-brown ferruginous limestone from a thin edge to 8 feet thick. This bed is too lenticular to serve as a key bed, but it was found to be useful in positively identifying the thin fossiliferous bed in the Buck Point sandstone.

ROCKS NOT EXPOSED.

The rocks in T. 27 N., R. 11 E., below the surface beds and above the top of the bed called by the drillers the "Mississippi lime," are known from a study of about 45 records of wells that have been drilled for the most part in the western half of the township. The accompanying table, which has been completed from these records, shows the depth from the surface of the ground to the top of several prominent beds and the thickness of these beds. The location of the wells described in the table is shown in figure 43.

[1] U. S. Geol. Survey Bull. 686–I, 1918.

Well data in T. 27 N., R. 11 E., Oklahoma.

No. in figure 43.	Location. Section.	Location. Quarter.	Depth to top of Big lime.	Depth to top of "Oswego lime."	Depth to top of Bartlesville sand.	Thickness of "Mississippi lime."	Depth to top of "Mississippi lime."	Total depth.	Name or position of pay sand.	Thickness of pay sand.	Type of well.	Initial daily production.
			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		Feet.		
1	2	SE.						688			Dry	
2	2	SE.		1,418	1,736	28		2,013	Bartlesville sand	28	Abandoned gas well	
3	2	NE.						641			Dry	
4	5	SE.		1,370	1,686	20	1,850	1,886			do	
5	6	SE.		1,446	1,760	25		1,938			do	
6	7	SW.	1,380	1,535			1,964	1,991	"Mississippi lime"		Abandoned oil well	
7	8	SE.						742	Stray sand (730-742 feet)	12	Gas well	3,061,800 cubic feet.
8	9	NE.			1,773	18		1,994			Dry	
9	13	SW.						1,607			do	
11	17	SE.		1,439			1,908	1,932			do	
12	17	SE.		1,435			1,898	1,927	"Mississippi lime"	29	Oil well	20 barrels.
15	18	NW.	1,378	1,538			1,980	2,022	do	42	do	70 barrels.
17	18	NW.	1,345	1,505			1,949	1,995	do	5	do	25 barrels.
18	18	NW.	1,358	1,512			1,952	2,012	do	50	do	70 barrels.
19	18	SW.	1,301	1,453	1,720	5	1,894	1,904	do	10	Gas well	4,000,000 cubic feet.
20	18	SW.	1,285	1,440			1,868	1,886	do	5	do	3,500,000 cubic feet.
21	18	SW.	1,286	1,439			1,874	1,895	do	21	do	2,750,000 cub.c feet.
22	18	SW.	1,285	1,435			1,869	1,881	do	12	do	4,000,000 cubic feet.
24	19	SW.					1,802	1,831	do	29	Oil well	20 barrels.
25	19	SE.	1,304	1,464			1,911	1,952	do	7	Gas well	1,600,000 cubic feet.
26	20	SW.	1,245	1,450	1,752	22	1,920	1,995			Dry	
30	20	NE.	1,280	1,435			1,898	1,921	"Mississippi lime"	29	Oil well	
46	27	SW.		1,450				1,941				
48	28	SW.	1,208	1,366	1,671	10	1,832	1,860	"Mississippi lime"	28	Gas well	5,000,000 cubic feet.
50	28	NW.	1,260	1,426	1,740	17	1,901	1,912	do	11	do	3,000,000 cubic feet.
57	29	NW.	1,266	1,423	1,745	15	1,898	1,914	do	16	do	2,500,000 cubic feet.
58	29	NW.	1,173	1,305	1,650	2	1,792	1,808	do	16	do	1,500,000 cubic feet.
59	29	NW.	1,179	1,338	1,668	12	1,818	1,890			Dry	
63	30	NE.	1,315	1,452	1,780	20	1,922	1,957	"Mississippi lime"	21	Oil well	25 barrels.
65	30	NW.	1,250	1,410			1,789	1,888	do		do	10 barrels.
67	30	NW.					1,723	1,865	do	26	do	20 barrels.
72	30	NW.		1,372			1,823	1,833	do	10	do	10 barrels.
73	31	SW.	1,237	1,388	1,740	20	1,885	1,900	Bartlesville sand	20	Abandoned oil well	
74	31	SW.	1,204	1,360	1,717	13		1,747	do	13	Oil well	100 barrels.
75	33	NW.	1,257	1,418	1,732	15	1,892	1,910	do	15	do	60 barrels.
76	33	NE.			1,662	12		1,839	do	12	Abandoned gas well	
77	33	NE.		1,320	1,627	18		1,645	do	18	Oil well	
78	33	NE.		1,300	1,606	10		1,616	do	10	do	
79	33	NE.		1,278	1,624	15		1,667	do	15	do	
80	33	NE.		1,250	1,579	11		1,608	do	11	do	

Well data in T. 27 N., R. 11 E., Oklahoma—Continued.

No. in figure 43.	Location.		Depth to top of Big lime.	Depth to top of "Oswego lime."	Depth to top of Bartlesville sand.	Thickness of "Mississippi lime."	Depth to top of "Mississippi lime."	Total depth.	Name or position of pay sand.	Thickness of pay sand.	Type of well.	Initial daily production.
	Section.	Quarter.										
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		*Feet.*		
81	33	NE.	....	1,305	1,651	17	....	1,693	Bartlesville sand	17	Oil well	
82	33	SE.	....	....	1,666	....	....	1,727	do	(?)	do	75 barrels.
83	33	SE.	....	....	1,645	16	....	1,661	do	16	Abandoned oil well	50 barrels.
84	34	SW.	....	1,300	1,634	6	....	1,655	do	6	Oil well	
85	34	SW.	....	1,325	1,662	16	....	1,701	do	16	do	
86	34	SW.	....	1,360	1,680	13	....	1,693	do	13	do	
87	34	SW.	....	....	1,687	8	....	1,706	do	8	Abandoned oil well	
95	36	NW.	....	....	....	....	....	1,057	Stray sand (975–1,042 feet)	67	Oil well	10 barrels.

Plate XLII shows graphically four fairly representative well logs and a generalized section indicating the relation between the exposed and unexposed rocks. The subsurface rocks represented in the generalized section consist of about 75 per cent shale, 14 per cent sandstone, and 11 per cent limestone. On the whole these rocks do not "cave" badly when drilled, so that it is a universal practice in the township to use cable tools rather than a rotary for drilling.

The first prominent "lime" usually recorded by the drillers, called by them the Little lime, is about 1,150 feet below the top of the Labadie limestone, which is exposed in the northwestern part of the township. The Little lime has an average thickness of about 28 feet and is separated from the exposed rocks by alternate beds of shale and sandstone interbedded with few thin beds of limestone.

After going through the Little lime the drill usually encounters about 120 feet of shale before reaching the next prominent limestone, commonly called by the drillers the Big lime. The Big lime has an average thickness of about 75 feet and in most of the well records it was reported to be made up entirely of limestone, although in a few a relatively thin parting of black shale was recorded. In other parts of the Osage Reservation oil and gas are produced from this bed, but no production of importance has been recorded from this township. This limestone is probably of the same age as the Oologah limestone, which crops out about 30 miles east of T. 27 N., R. 11 E.

The Big lime overlies the "Oswego lime" and is separated from it by about 80 feet of shale. The "Oswego lime" has an average thickness of approximately 70 feet, and its depth below the surface as well as its thickness is usually noted in records kept by the drillers. It is perhaps the most universally recognized subsurface bed in the township and is probably to be correlated with the Fort Scott limestone, which crops out about 50 miles east of this township. Although oil and gas are found in the "Oswego lime" in other parts of the Osage Reservation no production has been recorded from this bed in T. 27 N., R. 11 E.

The interval between the "Oswego lime" and the underlying sandstone, called the Bartlesville sand, averages about 260 feet and is largely filled with shale, interbedded near the top with relatively thin beds of sandstone and limestone. The Bartlesville sand, as shown in the table of well data with this report, or a sand in a similar stratigraphic position, is found over the greater part of this township that has been drilled. As shown in the table of well data, the maximum thickness of this sandstone is 27 feet in well 2 (fig. 43), in the SE. ¼ sec. 2; an average thickness is about 15 feet; and a number of the well logs, particularly those in secs. 17 and 18, did not record any sandstone at this stratigraphic horizon. It is pointed out in another part of this report that there is little relation between the oil and gas productivity and the thickness of the Bartlesville sand in this township, but that the oil production from this sand is partly controlled by its porosity. A study of the well records available indicates that in the area marked by shading in figure 43 the Bartlesville sand is more porous than elsewhere in the township.

A limestone, known as the "Mississippi lime," is found about 145 feet below the base of the Bartlesville sand. The interval of 145 feet is made up largely of shale, which is interbedded with a few thin limestones, and in one or two well logs a thin sandstone was also recorded in this interval. In a number of the records a part of the shale between the Bartlesville sand and the "Mississippi lime" is reported as black shale. Most of the oil that has been produced in this township is found in either the Bartlesville sand or the "Mississippi lime," and as the black shale is between these beds there is a possibility that it may have been the source of the oil. Black shale is also reported in a few well logs in the interval between the base of the "Oswego lime" and the Bartlesville sand. The total interval between the base of the "Oswego lime" and the top of the "Mississippi lime" may be the stratigraphic equivalent of the Cherokee shale, but the possibility that the black shale, which in some well logs is shown to lie immediately above the "Mississippi lime" and beneath the Bartlesville sand, may also be of Mississippian age, should at least be considered.

As shown in the table of well data the "Mississippi lime" has been penetrated by the drill to a maximum depth of about 75 feet in well 26, in sec. 20. (See fig. 43.) The bottom of the hole was still in the lime at this locality, consequently the thickness of the lime is greater than 75 feet. The "Mississippi lime" is tentatively classed as the stratigraphic equivalent of the Boone limestone, which is of Mississippian age, and if this correlation is correct it may be expected that the "Mississippi lime" will be several hundred feet thick. Before this correlation is conclusively made, however, the possibility of correlating the "Mississippi lime" with other Mississippian limestones younger than the Boone limestone should be considered. In parts of Oklahoma the Morrow group and Pitkin limestone, the latter of Mississippian age, are known to occupy a position below the Cherokee shale and above the Boone limestone, and they are separated from the Boone by shales and sandstone representing the Fayetteville formation and Batesville sandstone. The possibility of obtaining oil or gas from these sandstones between the Boone and the overlying limestones stamps this problem as one of direct economic importance, and consequently it is appropriate here to consider means of determining the correct correlation of the "Mississippi lime." It is generally agreed that the Boone is very siliceous, much more so than

the limestones of the Morrow and Pitkin. This means that the Boone should be harder to drill than the Morrow or Pitkin, the silica in the lime making it difficult to keep the bit sharp and in general preventing rapid drilling. The "Mississippi lime" produces both oil and gas in this township, and in some wells it is "shot" to increase its yield. It should be possible to collect, under favorable circumstances, chunks of the "Mississippi lime" from these wells that are shot and to examine them for fossils and their content of silica.

STRUCTURE.

CONVERGENCE OF STRATA.

Whether the producing oil and gas sands are parallel to the beds at the surface of the ground is a very important economic question, because it affects the depth of hole necessary to test the productive sands. By using the information embraced in the table of well data, and by comparing the relative elevations of subsurface beds with the surface structure, taking average rather than extreme results, the conclusions presented below have been developed.

In general the interval between a surface bed and an oil or gas sand is greater in the southwestern part of the township than it is in the northwestern part. The interval between any particular surface bed and the top of the "Oswego lime" is approximately the same in the southwest corner of sec. 31 as it is in the southwest corner of sec. 28, but in the northwest corner of sec. 18 the interval between the same surface bed and the "Oswego lime" is about 30 feet less. In other words, there is a convergence of about 30 feet toward the northwest between the beds at the surface and the "Oswego lime" at the localities mentioned above. From evidence obtained in T. 27 N., R. 10 E., the adjoining township on the west, it is likely that the total convergence toward the north between the surface beds and the "Oswego lime" from the southwest corner of T. 27 N., R. 11 E., to the northwest corner of this township amounts to about 100 feet.

A number of well logs showing the thicknesses of strata between the "Oswego lime" and the "Mississippi lime" were assembled, and the results averaged and distributed according to sections in the township. This showed that there is a convergence toward the north and west between the "Oswego lime" and the "Mississippi lime," which amounts to about 40 feet between sec. 31 and sec. 18, and about 60 feet between sec. 31 and sec. 7. Although the "Mississippi lime" is not parallel to the "Oswego lime" it does not seem that the discordance is due to an unconformity. More probably, inasmuch as the convergence of the beds above the "Oswego lime" is similar in amount and direction to that of the beds below it, the discordance of dip is logically explained by the fact that the whole section is thinner in the northern part of the township than it is in the southern part. This convergence of the strata means that a well drilled in the southwest corner of the township and starting on the Cheshewalla sandstone should reach the "Mississippi lime" at a depth of about 1,950 feet, whereas a well drilled in sec. 18 and starting on the Cheshewalla sandstone should reach the "Mississippi lime" at a depth of about 1,880 feet, and a well in sec. 6 which started on the same sandstone should reach the lime at a depth of about 1,800 feet.

GENERAL STRUCTURAL FEATURES.

The geologic structure of T. 27 N., R. 11 E., is shown on Plate XLI by means of structure contours that have an interval of 10 feet and are based entirely on surface data. The datum on which the contours are drawn is a theoretical bed 560 feet below the top of the Plummer limestone member of the Pawhuska limestone. A hasty glance at the structure contours leaves the impression that there is no normal dip in the township; rather the structure appears to be made up of irregular dips that form anticlines, domes, terraces, and synclines. However, a closer scrutiny of the map shows that the highest structure contour in the township is in sec. 36, at the southeast corner, and is the 1,070-foot contour, and that the lowest contour (labeled 740 feet) is in sec. 6 at the extreme northwest corner of the township. The general direction of dip, then, is toward the northwest and amounts to about 40 feet in a mile. Both the direction and amount are those generally accepted as representing the normal dip in this part of Oklahoma.

In figure 42 the axes of the principal domes and anticlines are outlined, and for convenience in description and reference these structural features are named. Most of the names are those of the allottees who have title to the land covered by the anticlines and domes. Inasmuch as domes, anticlines, and terraces are generally conceded to be more favorable for the accumulation of oil and gas than rock folds of other types, the areas covered by these structural features are briefly described below.

The Backius anticline plunges steeply toward the southwest and is characterized by relatively steep dips. The axis, as shown in figure 42, intersects the east line of sec. 36 near its northeast corner and the west line of the same section near its southwest corner.

The axis of the Doe Creek dome has a northwesterly trend and cuts across the southwest corner of sec. 34. (See fig. 3.) If the structure contours of this township are matched with those of the township immediately to the south (T. 26 N., R. 11 E.), it will be noted that the Doe creek dome has a closure between 50 and 60 feet.

The Sand Creek anticline might be described as an elongated dome whose axis has a northeasterly trend. It occupies the greater part of sec. 31 and extends into sec. 6 of T. 26 N., R. 11 E. By matching the contours shown on Plate XLI with those of T. 26 N., R. 11 E., it will be seen that the Sand Creek anticline has a closure of 20 to 30 feet.

Over a large part of sec. 30 and a part of the S. ½ sec. 19 the structure contours show that the rocks are practically flat-lying, and this structural feature is named the Levelette terrace.

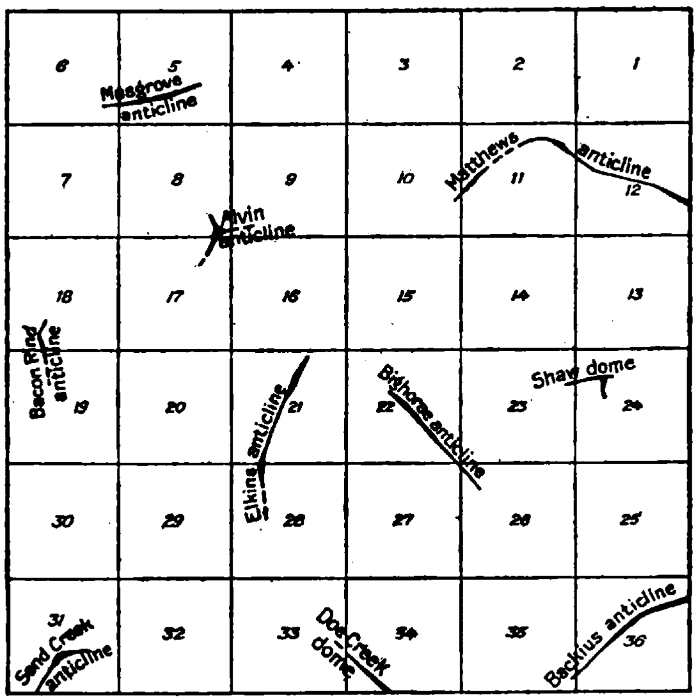


FIGURE 42.—Diagram showing approximate position of anticlinal axes in T. 27 N., R. 11 E.

The northern edge of the Levelette terrace merges into the Bacon Rind anticline, which covers a part of the N. ½ sec. 19 and a part of the S. ½ sec. 18. The axis has a southerly trend which toward the south is inclined to be slightly southeast.

The axis of the Elkins anticline cuts across sec. 21 with a northeasterly trend, and the anticline itself has relatively steep dips on its northwest, southeast, and southwest flanks. Its crest is structurally between 10 and 20 feet higher than the saddle on its northeast end, or in other words the anticline has a closure of 10 to 20 feet.

The Bighorse anticline is just east of the Elkins anticline and is connected with it by the structural saddle in the NE. ¼ sec. 21. The axis of the Bighorse anticline, which has a southeasterly trend, intersects the southeast corner of sec. 22 and extends into sec. 26. The anticline might be described as an elongated dome with a closure between 30 and 40 feet.

The Shaw dome is a relatively small structural feature which occupies the greater part of the W. ½ sec. 24 and a small part of the E. ½ sec. 23. It has a closure between 10 and 20 feet and is connected with the Bighorse anticline by a small structural saddle in sec. 24.

A part of the NE. ¼ sec. 13 and a smaller part of the SE. ¼ sec. 12 are covered by a small structural feature called the Rutter terrace. The structure contours show a flattening of the strata at this locality.

The Matthews anticline is shown on the contour map as a curved anticline with gentle dips which tends to encircle an area to the south of it that is structurally depressed.

The crest of the Alvin anticline is just west of the SE. ¼ sec. 8, and the anticline itself is characterized by well-developed dips to the south, west, and north. To the east there is possibly a dip of 10 feet which represents the closure of the anticline.

The Musgrove anticline covers a part of the SE. ¼ sec. 6 and the central part of sec. 5. This anticline has a closure of less than 10 feet and is characterized by gentle dips in all directions from its axis. Its axis, as shown in figure 42, has a southwesterly trend and cuts diagonally across the S. ½ sec. 5.

A glance at figure 42 leaves one with the impression that there is very little general trend for the anticlinal axes in T. 27 N., R. 11 E. One anticline may be connected with another by a structural saddle, but their axes may be nearly at right angles to each other. The disposition of the anticlines and domes about the large structurally depressed areas presents an arrangement similar to that which might result from the sinking of small areas and the upward buckling of bounding areas under tangential and torsional stresses. The economic application of this principle is that in this township it is very difficult to determine even approximately the position of an unmapped anticline by extending the trend of the axis of one that has been mapped.

There seems to be a broad relationship between the structure and the topography of this township. The principal divides are for the most part areas of upfolds, and many of the stream valleys coincide with structurally depressed areas. However, this generalization must be used with extreme care in forecasting the structure of an area in this township, because in detail there are so many exceptions to the rule that it is difficult to apply it except as a generalization.

SAND CONDITIONS.

General features.—The condition of the productive sand is one of the very important factors that control the production of oil or gas from any area. If the sand is too tight to serve as a reservoir it will not carry oil or gas in commercial quantities, and this condition or the absence of the sand may be more important than the structure of an area in determining its production.

In T. 27 N., R. 11 E., there are two main oil and gas producing beds, the "Mississippi lime" and the Bartlesville sand, and in addi-

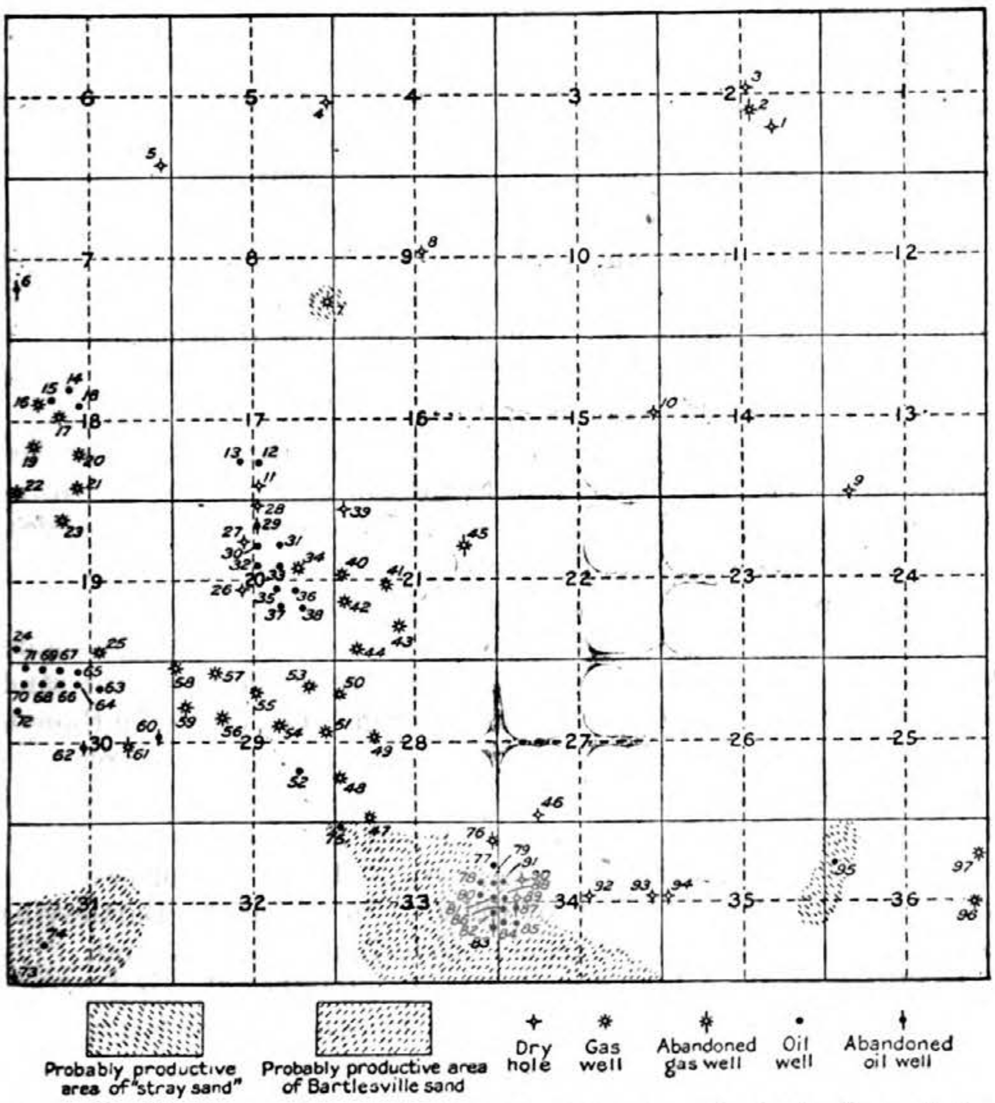


FIGURE 43.—Sketch map showing development work and productive territory of stray sands and Bartlesville sand in T. 27 N., R. 11 E.

tion several shallow oil-bearing sands that are called "stray sands" because they are local in their distribution and can not be correlated with any bed that is productive over a wide area. Figure 43 is designed to show the wells, dry holes, and abandoned wells, which are numbered to agree with the table of well data, on pages 259–260, the probable productive area of the stray sands, and the probable productive area of the Bartlesville sand. The shaded areas are purposely not definitely outlined but are left with irregular edges, for at best they represent estimates which can only approximate the actual productive area as proved by the drill. Both the shaded and the unshaded portions of the map represent territory that may be productive of oil or gas from the "Mississippi lime" provided the structure is favorable.

Stray sands.—Well 7, in the SE. ¼ sec. 8, produces gas from a sand between 730 and 742 feet below the surface and is reported to have had an initial production of over 3,000,000 cubic feet of gas per day. The productive area of this stray sand is conservatively shown in figure 43 as surrounding well 7 for a distance of about 600 feet in all directions. This is the only well that is reported to be productive from a sand at this position in the stratigraphic column.

In figure 43 there is outlined approximately the productive areal distribution of a stray sand that is found in secs. 35 and 36 about 1,000 feet from the surface. Well 95 is the only well listed in the table that shows production from this sand, but information from trade journals and other sources forms the basis for extending the productive area of this sand as outlined in figure 43.

Bartlesville sand.—The probably productive area of the Bartlesville sand (see fig. 43) is confined to the southern part of the township, covering appreciable parts of secs. 31, 33, and 34. The Bartlesville sand, or a sand in a similar position in the stratigraphic column, has been recorded in a large number of the wells drilled in this township, many of them outside of the area indicated by shading in figure 43. This probably means that outside of the shaded area the sand is too tightly cemented to serve as an oil or gas reservoir, even though it is thicker in some places than it is within the productive area.

It follows from this that the Bartlesville sand should be shot if there is a show of oil in the sand in any part of the township. In the adjacent township on the west (T. 27 N., R. 10 E.) one or two wells which are considerably north of the area in which the Bartlesville sand is generally productive report production from this sand.

As shown in the table of well data, the Bartlesville sand within its productive area attains a maximum thickness of 20 feet in well 73, sec. 31, and its minimum recorded thickness is only 6 feet, in well 84, in the SW. ¼ sec. 34. The initial production of four wells producing from the Bartlesville sand ranges from 50 to 100 barrels of oil a day.

"*Mississippi lime.*"—The oil and gas that have been produced from the "Mississippi lime" in this township come from the upper 50 feet of this limestone. All the wells shown in figure 43, except those within the shaded areas, produce from the "Mississippi lime." As the wells within the shaded areas tap sands that are shallower than the "Mississippi lime," that bed has not been tested in these areas. Production from the "Mississippi lime" is more widely distributed than from any other bed, and in fact the statement seems warranted that wherever in T. 27 N., R. 11 E., the geologic structure is favorable there is a very good chance of obtaining either oil or gas from the "Mississippi lime." The average initial production of the wells in this township from the "Mississippi lime" is about 24 barrels of oil a day. An initial production above 30 barrels or below 10 barrels a day is rare.

Possible productive sands below the "Mississippi lime."—In other parts of Oklahoma production of oil has been reported from sands more than 300 feet below the top of the "Mississippi lime." The following is an informal communication from Mr. R. H. Wood, dated January 25, 1919, concerning the possibility of obtaining oil from such lower beds:

> The oil limitations are not reached at the top of the "Mississippi lime" in northeastern Oklahoma, as oil has been found in a number of localities by drilling into or through that formation some 300 feet.
>
> Concrete examples may be found in the Barnsdall Oil Co.'s wells Nos. 374 and 407, in sec. 8, T. 20 N., R. 12 E. In the former well the "Mississippi lime" was reached at 1,850 feet and the top of a sand at 2,125 feet, which continued to 2,178 feet. This is 275 feet below the top of the lime. This deep sand produced initially, according to the superintendent, 1,000,000 feet of gas and 312 barrels of oil a day. Farther west, in sec. 14, T. 22 N., R. 8 E., the Red Bank Oil Co. has within the last two weeks completed a "Mississippi lime" well, but no data are available except those appearing in the trade journals. It is reported that the "Mississippi lime" was found at 2,545 feet and some oil at 2,579 feet. A sand was found at 2,850 feet, and drilling continued to 2,886 feet. The well is now said to be producing 30 barrels daily, presumably from the deep sand.
>
> In T. 20 N., R. 11 E., the Phoenix Refining Co. has drilled a number of wells near Sand Springs some 300 feet below the top of the "Mississippi lime" and obtained oil there. The first of these wells was reported to produce initially 1,500 barrels daily. This oil is of very high grade.
>
> Between Sapulpa and Tulsa, and nearly east of Sapulpa, some wells have been drilled several hundred feet into the "Mississippi lime" and produce high-grade oil.
>
> With meager data in hand it is impossible to determine in every instance whether the "Mississippi lime" is Boone or Morrow and Pitkin.

Other reports concerning the production of oil from sands well below the top of the "Mississippi lime" have appeared in the daily press from time to time. In sec. 25, T. 27 N., R. 10 E., less than a mile from the western edge of T. 27 N., R. 11 E., a well is reported to have obtained 1,500,000 cubic feet of gas a day from a sand more than 300 feet below the top of the "Mississippi lime."

It seems clear that in order to test conclusively any area that is favorably located with reference to structure the test hole should be drilled to a depth of 400 feet below the top of the "Mississippi lime."

AREAS OF FAVORABLE STRUCTURE FOR THE ACCUMULATION OF OIL AND GAS.

GENERALIZATIONS.

In outlining the areas which are believed to represent territory that gives greater promise for the production of oil or gas than areas not so outlined, the writers have used certain generalizations which are based primarily on the relation between structure and production that has been found to prevail over a large part of the Osage Reservation. In general the crests of the anticlines and domes are more likely to be productive of gas than of oil. The western flank of an anticline is more likely to be productive of oil than the eastern flank, and production may be expected farther down, structurally, from the crest of the fold on the western flank than on the eastern flank. The large anticlines and domes with high closure should be rated better than terraces or anticlines with small closure, although broad terraces or anticlines with small reversals and gentle dips that cover several sections are known to produce oil and gas in T. 27 N., R. 11 E., and in other townships in the Osage Reservation. Until more intensive work is done in this region on the relation between surface structure and the production of oil and gas it is difficult to go further than the statements outlined in the generalizations above. Therefore, even if the sands that carry the oil and gas were equally open and porous throughout the township, it would not be possible now, ahead of the drill, to outline definitely the productive areas of the several structural features of the township. As a matter of fact it is known that the sands are not equally open and porous, and so the difficulty of definitely outlining the productive areas is increased. Hence the outlines of the productive areas as set forth below must not be considered mathematically exact, but they represent an attempt on the part of the writers to give the reader their best guess or estimate of the more favorably located areas for prospective oil and gas territory. It is therefore emphasized that the recommendations made below do not in any way guarantee that oil or gas will be found in the favorably located areas, but it is believed that by first testing these favorable areas futile drilling and expense will be saved and in general the township as a whole will be developed more efficiently than by promiscuous drilling.

ANTICLINES, DOMES, AND TERRACES.

BACKIUS ANTICLINE.

Stray sand.—The probable productive area of the sand found in well 95 between 975 and 1,042 feet from the surface is indicated in figure 43. The productive area of this sand may probably be extended to the north, west, and south of the shaded area to conform with what is regarded as the productive area of the "Mississippi lime." It has been reported through the press that a well was drilled in the SW. ¼ NW. ¼ sec. 36 to the "Mississippi lime" and obtained 2,000,000 cubic feet of gas a day. Presumably there was no production in the stray sand at this locality so the productive eastern limit of this stray sand probably can not be extended much beyond the shaded area.

Bartlesville sand.—The record of the well mentioned in the paragraph above, which produced 2,000,000 cubic feet of gas a day from the "Mississippi lime," reported the Bartlesville sand to be dry. If the Bartlesville sand is found to be productive at all on the Backius anticline, the productive area will probably cover the southern tier of 40-acre tracts in sec. 36 and possibly a part of the SE. ¼ sec. 35. As the sand is probably tightly cemented it should be shot if the drill uncovers a good showing of oil. At the date of this writing (February, 1919) there is no evidence at hand that oil or gas has been obtained from the Bartlesville sand on the Backius anticline.

"*Mississippi lime.*"—On the assumption that the "Mississippi lime" is likely to be productive of oil or gas where the structure is favorable, it may be expected that this limestone will yield either oil or gas in the greater part of sec. 36, a large part of the S. ½ sec. 25, and the central and southern parts of the E. ½ sec. 35. Probably that part of the area in this township which includes the structure contours above the 1,020-foot contour will be productive, principally of gas from the "Mississippi lime."

DOE CREEK DOME.

Stray sands.—There is no particular reason to believe that oil or gas will be obtained from beds above the Bartlesville sand on the undrilled part of the Doe Creek dome, for the drilling that has been done has not disclosed any such productive beds. Because of the fact, however, that stray sands are irregular in their distribution there is always a chance in a large undrilled area that production may be obtained from such sources.

Bartlesville sand.—The probable productive area of the Bartlesville sand as outlined in figure 43 covers a good portion of the Doe Creek dome. The shaded area was drawn so as to include a large part of the west flank of the dome and a relatively small part of the east flank. Well 82 had an initial daily production of 75 barrels, well 83 an initial production of 50 barrels, and well 75, which probably should be classed with the Elkins anticline, an initial production of 60 barrels. As recorded in the table of well data, the thickest measurement of the Bartlesville sand in the area covered by this dome was 18 feet and the minimum measurement 6 feet.

"*Mississippi lime.*"—The productive area of the "Mississippi lime" on the Doe Creek dome probably coincides fairly well with the productive areas as outlined for the Bartlesville sand. None of the wells on this dome recorded in the table of well data were deep enough to test the "Mississippi lime," and so it can not be stated from actual tests whether or not this limestone is productive in this locality. However, as the "Mississippi lime" has yielded either oil or gas in practically all the wells that have been drilled in this township in areas of favorable structure, it is reasonable to assume that there is a good chance of obtaining such production here by deepening the present wells or by drilling others deep enough to reach the lime.

SAND CREEK ANTICLINE.

Stray sands.—No production of oil or gas from sands above the Bartlesville sand has been recorded in the wells that have been drilled on the Sand Creek anticline, and although there is a possibility of tapping small local lenses or stray sands here it must be classed as a possibility rather than a probability.

Bartlesville sand.—The probable productive area of the Bartlesville sand on the Sand Creek anticline, as shown in figure 43, covers a large part of sec. 31. Wells 73 and 74 are reported to have produced oil from the Bartlesville sand, and well 74 is credited with an initial daily production of about 100 barrels. The sand in these two wells was 20 and 13 feet thick, respectively. The shaded area is controlled by the structure contours of the Sand Creek dome and is so outlined as to cover more of the northwestern flank of the anticline than the southeastern flank.

"*Mississippi lime.*"—Well 73 is reported to have penetrated the "Mississippi lime" to a depth of 15 feet without getting oil or gas. It is believed, however, that this result does not condemn the "Mississippi lime" for the Sand Creek dome, and that the Bartlesville sand wells should eventually be deepened so as to test this horizon thoroughly. The area outlined as probable oil and gas territory for the Bartlesville sand might be put in a similar class with respect to the "Mississippi lime."

LEVELETTE TERRACE.

Stray sands and the Bartlesville sand.—On the Levelette terrace a number of wells have been drilled through the Bartlesville sand, and no oil or gas has been obtained either in this sand or in any sands above it. Inasmuch as this structural terrace has been fairly tested by these wells it is probable that the Bartlesville sand or the sands above it will not supply any large amount of oil or gas here.

"*Mississippi lime.*"—A number of wells which produce both oil and gas from the "Mississippi lime" have been drilled on the Levelette terrace. The initial production of these wells ranges from about 10 barrels to 25 barrels of oil a day. In a general classification the major part of the N. ½ sec. 30 and of the SW. ¼ sec. 19 may be considered oil territory, and the territory along the crest of the anticline which connects the Bacon Rind anticline with the Levelette terrace will probably be productive of gas. This gas territory will probably cover substantial portions of the SE. ¼ and NW. ¼ sec. 19.

BACON RIND ANTICLINE.

Stray sands and the Bartlesville sand.—The Bartlesville sand and the horizons of stray sands above it have been pierced by the drill on the Bacon Rind anticline, but no oil or gas has been obtained from them. It may be concluded that these sands will furnish very little oil or gas in the area covered by this anticline.

"*Mississippi lime.*"—The crest of the Bacon Rind anticline is proved gas territory, and the gas comes from the "Mississippi lime." The initial production of these wells ranges from about 2,500,000 to 4,000,000 cubic feet of gas a day. This gas territory covers practically all of the SW. ¼ sec. 18, and, as stated in the discussion of the Levelette terrace, it will probably be found to extend diagonally across sec. 19. Oil has been found over a part of the northern flank of the Bacon Rind anticline, and the record of wells 15 and 18 (see table, p. 259) show an initial daily production of 70 barrels each from the "Mississippi lime." The prospective oil territory on the north flank of the Bacon Rind anticline can probably be extended at least 1,000 feet north of well 14, and toward the northwest it may be limited by the 790-foot structure contour (Pl. XLI). Although the eastern flanks of the anticlines in the Osage Reservation are commonly not as productive as the western flanks, there are exceptions to this rule, and the W. ½ SE. ¼ sec. 18 may be classed as territory in which there is a chance of obtaining oil from the "Mississippi lime," and this territory may be extended for a short distance into the NE. ¼ sec. 19.

ELKINS ANTICLINE.

Sands above the "Mississippi lime."—The Bartlesville and higher sands have been very well tested by the wells drilled through them on the Elkins anticline, but no production of oil or gas (except that obtained from well 75, which is discussed under the Doe Creek dome) from these sands is recorded in the table of well data. It is not improbable that the Bartlesville sand will be found to be productive in parts of the SW. ¼ sec. 28 and the SE. ¼ sec. 29. If in drilling these areas a show of oil is found, the sand should be shot, for this territory borders the northern boundary of the productive area of the Bartlesville sand, and the sand is unproductive probably because it is tight or closely cemented.

"*Mississippi lime.*"—The "Mississippi lime" has furnished practically all the oil and gas obtained on the Elkins anticline. Drilling has proved that the greater part of the anticline must be considered gas territory, although some oil has been found well down on its northwestern and southwestern flanks. The maximum initial daily production recorded for a gas well on this anticline is 5,000,000 cubic feet, and the average initial daily production of the oil wells on the northwestern flank of this fold is probably about 25 barrels. The prospective oil territory may reasonably be expected to extend southward from well 37 to the gas territory in the NE. ¼ sec. 29, and northeast of the productive area in the NE. ¼ sec. 20 it may be extended to include the area between wells 39 and 40, a part of the SE. ¼ SW. ¼ sec. 16, and a part of the SW. ¼ SE. ¼ sec. 16. It is not improbable that a narrow strip of productive oil territory will be found to border the southwestern edge of the gas territory in sec. 29.

BIGHORSE ANTICLINE.

The Bighorse anticline has not been tested with the drill for oil or gas, and therefore the sand conditions over this area are unknown. The anticline is probably north of the productive area of the Bartlesville sand in this township, and unless a stray sand is found, which, of course, could not be predicted in advance of the drill, the "Mississippi lime" must be considered the most probable source of production. All the territory surrounded by the 950-foot structure contour (Pl. XLI), which includes a large part of sec. 22, a part of the SW. ¼ sec. 23, the NW. ¼ sec. 26, and a part of the NE. ¼ sec. 27, should be classed as structurally favorable for the accumulation of oil and gas. The central part of this oblong area is more likely to be productive of gas than of oil, and a strip a few hundred feet wide on the southwestern flank of the anticline may be found to produce oil southwest of the line made by the 950-foot structure contour.

SHAW DOME.

As the Shaw dome has not been tested with the drill for oil or gas the same conclusions relative to the sands may be applied to it that were applied to the Bighorse anticline—that is, that the dome is probably north of the productive area of the Bartlesville sand and that the "Mississippi lime" must be considered the most probable source of production here. The territory surrounded by the 950-foot structure contour may be conservatively classed as an area that is located more favorably with respect to structure for the accumulation of oil or gas than the surrounding territory. This area of favorable structure is believed to be less valuable as prospective oil and gas territory than the area covered by the Bighorse anticline, but more valuable than the area covered by the Rutter terrace, which is described below.

RUTTER TERRACE.

As the Rutter terrace is a relatively small structural feature its value as prospective oil or gas territory should be rated considerably lower than that of the Shaw dome or the other structural features which have been described above. The territory partly surrounded by the 910-foot contour, embracing a part of the S. ½ SE. ¼ sec. 12 and a part of the N. ½ NE. ¼ sec. 13, constitute the area most favorable for the accumulation of oil or gas. The Rutter terrace has not been tested with the drill, but it is probable that the "Mississippi lime" offers the most likely source of oil or gas here.

MATTHEWS ANTICLINE.

The value of the Matthews anticline as prospective oil and gas territory should be rated higher than that of the Rutter terrace and lower than that of the Shaw dome. The most likely area on the Matthews anticline for the accumulation of oil and gas may be roughly outlined as extending 600 feet on both sides of the axis (see fig. 42) of the anticline and embracing a strip with a northwesterly trend about a quarter of a mile wide across sec 12, a large fraction of the NE. ¼ sec. 11, and a strip with a northeasterly trend across the W. ½ sec. 11. The Matthews anticline has not been tested with the drill, but well 2, in the SE. ¼ sec. 2 (see fig. 43), is reported as an abandoned gas well that produced from the Bartlesville sand, which had a thickness of 27 feet. As this well is within half a mile of the Matthews anticline there is a chance that the Bartlesville sand may be open enough to yield oil or gas in the area outlined above. If this area is tested and a good show of oil or gas is found in the Bartlesville sand, the sand should be shot in order to test it thoroughly. The top of the "Mississippi lime" offers a better chance of obtaining oil or gas than the Bartlesville sand and, of course, should be tested if this anticline is drilled.

ALVIN ANTICLINE.

Stray sand.—Well 7 (see fig. 43) is reported to have had an initial production of over 3,000,000 cubic feet of gas a day from a sand 13 feet thick, found at a depth of 730 feet from the surface. The productive area of this sand is outlined in figure 43 as extending for 600 feet in all directions from the well, but it is not improbable that future drilling may show it to extend still farther.

Bartlesville sand.—Well 7, mentioned above, was not drilled deep enough to test the Bartlesville sand, but the wells in the southern part of sec. 17 were drilled through this sand without obtaining oil or gas. The probable productive area of the Bartlesville sand is shown in figure 43 to lie to the south of this anticline, so that, all things considered, it does not seem likely that any large quantity of oil will be obtained from the Bartlesville sand in the area covered by the Alvin anticline. However, if a good show of oil or gas is encountered in this sand it should be shot in order to test it thoroughly.

"*Mississippi lime.*"—The only records of oil produced from the "Mississippi lime" on this anticline were those of wells 12 and 13, in the southern part of sec. 17. (See fig. 43.) Well 12 is reported to have had an initial daily production of 20 barrels of oil from the "Mississippi lime." The territory in which gas may be obtained from the "Mississippi lime" on the Alvin anticline is estimated to include the area partly surrounded by the 880-foot structure contour, which embraces the territory surrounding the southeast corner of sec. 8. The western flank and part of the northern flank of the anticline between the 880-foot and 840-foot structure contours may be conservatively classed as having a better chance for oil production than the adjacent territory. This embraces the major part of the SE. ¼ sec. 8 outside of the gas territory, a very large part of the SW. ¼ sec. 8, and a large part of sec. 17. Oil has been produced as far down on the southwestern flank of the anticline as the 840-foot structure contour, and consequently the area between well 12 and the southeastern edge of the probable gas area, outlined above, may be classified as fairly promising oil territory. The territory east of the probable gas territory is not rated in regard to its oil value as high as the areas outlined above, but it is not improbable that oil or gas will be obtained on the terrace-like structural feature just east of the Alvin anticline.

MUSGROVE ANTICLINE.

Wells 4 and 5 (fig. 43), which were not located in the most favorable places structurally on the Musgrove anticline, were drilled through the horizons of the stray sands and the Bartlesville sand without getting oil or gas. It is probable that the "Mississippi lime" is the most promising source of oil or gas in the area covered by this anticline. The area surrounded by the 810-foot structure contour and also the area on the north and northwest flanks of the anticline between the 810 and 800 foot contours are classed as offering a better chance for oil or gas production than the territory immediately surrounding them. However, these areas should receive a general rating less favorable than that of the Alvin anticline and more favorable than that of the Matthews anticline.

QUALITY OF THE OIL AND GAS.

No attempt is made in this report to discuss analyses of the oil and gas that have been produced in this township. That discussion is reserved for the final report on the Pawhuska quadrangle. For the benefit of the man who is entirely unfamiliar with this field, however, it may be pointed out that the oil is of relatively high grade and is classed in price with the oil from the Cushing and Bartlesville fields.

GENERAL RECOMMENDATIONS.

No part of T. 27 N., R. 11 E., is absolutely condemned for oil or gas, because, even in areas where the structure is unfavorable, there is always a possibility of obtaining these substances from lenticular sands or sands in which the production is controlled by irregular cementation. However, if the areas that are located favorably with respect to the geologic structures are tested first, the risk of failure is very much lowered. The principal effort in geologic work of this type is to reduce that risk as much as possible, with the realization always in view that even on the soundest available evidence it is still impossible to outline productive areas definitely ahead of the drill.

The necessity and importance of testing the sands below the "Mississippi lime" are again emphasized. Such a test should first be made on the top of some well-developed structural feature, such as the Doe Creek dome, and if it is unsuccessful another well-developed anticline should be tested. It is recommended that the tests be carried to a depth of 400 feet below the top of the "Mississippi lime."

TPS. 21–23 N., RS. 6–7 E., AND TPS. 23–25 N., RS. 3–5 E.

By C. F. Bowen, P. V. Roundy, C. S. Ross, and Frank Reeves.

INTRODUCTION.

The Osage Reservation has, by general agreement, been divided into an eastern and a western portion. The eastern portion, commonly referred to as the "east side," includes that part of the reservation lying east of R. 7 E., and the "west side" includes that part lying west of R. 8 E. This report describes the southeastern part of the "west side," lying south of T. 24 N. and east of R. 5 E., and the western part, lying west of R. 6 E. and south of T. 26 N. (See fig. 1 and Pls. XLIII and XLIV.) It also includes small portions of T. 25 N., R. 5 E., and T. 24 N., Rs. 6 and 7 E., and shows slight revisions of the map of these townships as published in Bulletin 686–L. The field work was begun in October, 1918, and completed in February, 1919.

The key maps of Plates XLIII and XLIV show the areas mapped by the different geologists, who assume responsibility and are likewise to be accorded credit for the accuracy of the results in the respective areas as shown on the geologic maps. So far as practicable, too, the descriptions of the structure in the several townships were prepared by the geologists who did the field work.

Messrs. Charles Price, W. G. Argabrite, C. E. Dobbin, J. L. Mergner, and Walter Wilson served as instrument men during a part or all of the field season.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL FEATURES.

The rocks exposed from east to west across the southern part of the "west side" are illustrated graphically in the columnar section on Plates XLIII and XLIV. They have an aggregate thickness of about 1,500 feet and are of upper Pennsylvanian and lower Permian age. They consist of numerous beds of limestone, ranging in thickness from a few inches to 15 feet or more, interstratified with beds of sandstone and shale. The principal limestones are continuous from north to south across the entire "west side," but most of them show considerable change in physical character. As a rule the limestones become thinner and more sandy, and the sandstones between them become more prominent toward the south. Above the Neva limestone all the rocks except the limestones are prevailingly red; below the Neva more somber colors predominate, though some of the shales have reddish hues. The limestones are of the greatest aid in working out the structure of the region, hence the most prominent and characteristic of them will be described, but no detailed description of the stratigraphy as a whole will be given.

KEY BEDS.

Lecompton (?) limestone.—The limestone here designated the Lecompton (?) averages about 15 feet in thickness but attains limits considerably above and below that figure. It is known to the commercial geologists as the "Hominy lime." In the southern part of the area it comprises three more or less distinct limestone beds. The upper bed is a thin, platy, gray limestone 1 foot or less in thickness, containing an abundance of fossil *Fusulina.* It is separated from the middle limestone by about 5 feet of shale. The middle bed, which is 1 or 2 feet thick, lies immediately below the shale parting and is a dull-gray, slightly ferruginous limestone, which in some places weathers slightly brown. It is somewhat sandy in composition and as a result weathers to smooth surfaces. It is less resistant to erosion than the lower bed, and therefore as a rule weathers back under the grassy slopes which commonly mark the upper surface of the bed. The lower bed is a gray thin-bedded ledge-making limestone which weathers white. It is the most conspicuous part of the member and generally produces a marked ledge or rim. In vertical faces the thin regular layers of limestone cut by vertical joints present the appearance of an artificial rock wall. Heald[1] has correlated the "Hominy lime" with the Lecompton limestone, but the sequence of beds between the Elgin sandstone and the Bird Creek limestone, the intervals between them, and the lithologic character of the limestones themselves strongly suggest that the "Hominy lime" represents the Deer Creek limestone, and that the thin yellow limestone about 30 feet lower in the section is the equivalent of the Lecompton.

Turkey Run limestone.—The Turkey Run limestone lies about 85 feet above the Lecompton (?) limestone, and is 1 to 3 feet thick. It thins toward the south. The rock is a steel-blue dense, fine-grained

[1] Heald, K. C., and Mather, K. F., report on Tps. 24 and 25 N., R. 8 E.: U. S. Geol. Survey Bull., 686–M, p. 151, 1919.

brittle limestone that rings when struck with the hammer and breaks with a clean-cut fracture. It weathers into rectangular or wedge-shaped blocks, which do not erode easily and are therefore rather conspicuous even on grassy slopes. The most characteristic fossil is a species of small, slender *Fusulina* that is especially abundant in the lower part of the bed. These fossils are, however, most noticeable in the southern part of the area and were not observed in T. 23 N. Because of its thinness, persistence, and easily recognizable character this bed is a most valuable key rock in the areas where it is exposed.

Bird Creek limestone.—The Bird Creek limestone lies 52 feet above the Turkey Run limestone. It is 1 to 4 feet in thickness and thins toward the south. It is very similar to the Turkey Run limestone in physical character but differs slightly in color, mode of weathering, and fossil content. The Bird Creek limestone is dull black, breaks along bedding planes, and weathers into thin plates that scale off the surface parallel to the bedding. The *Fusulina* noted in the Turkey Run limestone were not observed in the Bird Creek limestone. However, considerable care has to be exercised to avoid confusing these two beds.

Cryptozoon-bearing limestone.—The *Cryptozoon*-bearing limestone is 105 feet above the Bird Creek limestone and has a thickness of at least 5 feet at the small outlier in the NW. ¼ sec. 35, T. 22 N., R. 7 E. In T. 23 N. it seems to be only about 2½ feet thick. It is a dense non-crystalline black or gray fossiliferous rock resembling in physical appearance the Bird Creek and Turkey Run limestones. It is distinguished from those beds by its fossils, which comprise *Fusulina*, Cryptozoa, and Bryozoa, besides other less distinctive forms. The *Fusulina* are of medium size and rather abundant and are present in the limestone over the entire area. The Cryptozoa, which are the most diagnostic fossils in this limestone farther north, are very rare in this area and were not observed south of T. 23 N. They occur most commonly in the somewhat limonitic upper portion of the bed. The Bryozoa occur in large circular, rosette-like colonies, as much as 3 or 4 inches in diameter. They are less soluble than the matrix in which they occur and hence are found loose on the surface of the bed or in the débris below it.

Stonebreaker limestone.—The Stonebreaker limestone includes three distinct beds of limestone ranging through an interval of about 55 feet and separated by beds of shale and sandstone. The lowest limestone is approximately 60 feet above the *Cryptozoon*-bearing limestone and is about 12 feet thick but gives the impression at most of the exposures of consisting of two or more beds, because certain layers that are somewhat more resistant to erosion than the remainder of the bed form shoulders separated by areas in which the rock is concealed. The upper part of the bed weathers white and in places is thickly dotted with spots of white calcite replacing gastropods. About 2 or 3 feet below the top is a layer containing some large, plump *Fusulina*. At the base is a thin yellow layer which is highly fossiliferous.

About 20 to 25 feet above the bed just described is a sandy gray limestone about 2 feet thick, which weathers into rounded masses or boulder-like forms. In places the weathered surface is strongly limonitized and brown, but the prevailing color is light gray. The bed is sparingly fossiliferous, and its chief distinguishable form is a species of small *Fusulina*. The limestone lies immediately above a persistent bed of sandstone and in some places is also overlain by a bed of sandstone. About 20 feet above the gray sandy limestone is a thin drab crystalline fossiliferous limestone lying immediately below a thick, heavy sandstone. This limestone is thin bedded and weathers down quickly, so that it is generally concealed by débris from the beds above. It is commonly exposed on projecting points and weathered fragments of it may be found at other places where the sandstone débris is not too heavy. A species of large *Myalina* is sparingly distributed in this bed. Aside from this the fossils are not distinctive and consist of fragmentary remains. A thin limestone very similar to this one occurs about 35 feet below the Grayhorse limestone and is the only other limestone likely to be confused with the upper bed of the Stonebreaker.

Grayhorse limestone.—The Grayhorse limestone lies about 90 feet above the top of the Stonebreaker limestone. It is 1½ to 2 feet thick and is the most easily recognized bed in the township. It is a drab crystalline conglomerate limestone which weathers to a dirty pale yellow and contains fossils of a large *Myalina*. The conglomerate pebbles are small, rarely more than a quarter of an inch in diameter, and consist chiefly of shale which weathers dirty bluish gray, giving to the surface of the rock a mottled aspect. The limestone as a rule weathers out in large thin slabs, but it does not produce any marked topographic effect on the landscape.

Foraker limestone.—The Foraker limestone, the base of which lies 100 feet above the Grayhorse limestone, includes a succession of sandstones, shales, and limestones about 110 feet thick. The limestones, which constitute about one-fourth of the unit, are characterized throughout by an abundance of *Fusulina*. For convenience of description the Foraker may be divided into three divisions. The lower division, about 45 feet thick, consists of two thin limestones at the base separated by about 10 feet of shale and overlain by about 35 feet of sediments—principally red shale, some of which is sandy, and one well-defined bed of sandstone. These basal limestones make excellent key beds. They are each about 1 foot thick. The upper one is lead-gray, and the lower one somewhat lighter in color. They produce small shoulders or terraces at the base of the steep slope formed by the upper limestones and weather out into large slabs, which, as a rule, represent the entire thickness of the individual beds.

The middle division of the Foraker consists of a single limestone overlain by a heavy sandstone in places at least 20 feet thick. The basal part of the limestone is dense, fine grained, and black, weathers in slabs, and is overlain by less resistant limestone which weathers slightly yellow and contains crinoid stems, brachiopods, etc.

The upper division comprises three well-defined limestones, with probably some thinner beds, separated by beds of gray shale. These limestones are all gray, weathering whitish. The lower one is blotched with yellow on the weathered surface and is characterized by an abundance of large round, plump *Fusulina* which weather brown. The next limestone above this contains long, slender *Fusulina* like rice grains and is overlain by a thin bed of orange-colored *Fusulina*-bearing limestone. At the top of the division is a gray limestone which weathers with smooth surfaces, shows few or no *Fusulina*, and contains a considerable amount of secondary calcite. This is the highest bed of the Foraker limestone.

Red Eagle limestone.—The Red Eagle is a gray limestone that weathers nearly white. Its exact thickness was not determined but in T. 24 N., R. 5 E., is at least 6 feet. On the fresh surface the prevailing color is gray tinged with yellow. In some places the yellow predominates, and in others it gives place to spots or streaks of red. The limestone contains a large amount of secondary calcite, which shows as numerous small, grainlike protuberances on the weathered surface. Fossils are not abundant, but brachiopods and fragments of other fossils occur. A thin bed about 15 feet below the Red Eagle contains abundant fossils, predominantly brachiopods. It crops out at the base of the steep slope formed by the Neva limestone and is of little importance as a key bed in this area because its line of outcrop is so close to that of the Neva. The base of the Red Eagle is about 30 feet above the top of the Foraker limestone.

Neva limestone.—The base of the Neva limestone lies about 115 feet above the top of the Foraker. The Neva consists of three distinct members. At the base is a gray crystalline nonfossiliferous thin-bedded limestone about 4 or 5 feet thick, which weathers to a clean white color and breaks out in large thin slabs. It commonly forms the main scarp of the Neva outcrop. This white member is directly overlain by 6 or 8 feet of dirty-yellow cherty limestone containing an abundance of fossil *Fusulina.* This cherty member breaks into small irregular platy pieces and is easily distinguished by its color and the presence of chert and *Fusulina.* Above the cherty member and probably separated from it by a few feet of shale is another white limestone quite similar in color to the white bed at the base but differing in that it commonly contains a few *Fusulina* and is slightly cherty, the weathered surface showing small protuberances of siliceous material. The total thickness of the Neva is about 12 feet.

This limestone is regarded by some geologists as forming the base of the Permian.

Cottonwood limestone.—The Cottonwood limestone lies about 105 feet above the lower member of the Neva and is a light-drab crystalline argillaceous and oolitic limestone that has a slight greenish or in places reddish tint on the fresh surface. It consists of two benches separated by 5 to 15 feet of shale. The lower bench is 2 feet thick at the north side of T. 24 N., R. 4 E., the only place where a clean-cut section of it was observed. The upper bench is probably 3 or 4 feet thick. The matrix of the limestone is distinctly argillaceous, and it is the color of this clayey material that imparts a slightly greenish tinge to the rock. Locally, these green spots resemble "copper stain." In places the clayey material is stained red and imparts a reddish tint to the limestone. Inclosed in the matrix are numerous small elliptical or oval bodies ranging in size from that of flaxseed to that of small rice grains. Many of these bodies exhibit a concentric structure under an ordinary hand magnifier and are clearly oolites; others may be pebbles. Examination of a polished surface would probably be necessary to determine whether all these bodies are oolites or, if not, to determine the ratio of oolites to pebbles. Most of the oolites have a dark central portion, which in cross section is scarcely noticeable but in longitudinal section appears as a dark narrow band. The weathered surface of the rock is pitted and uneven, having a somewhat gnarled appearance, and the small oolites stand out in slight relief, giving the surface a pimpled aspect. In some places the weathered grains have an outer shell of limonite and an inner body of calcite.

The limestone is only slightly fossiliferous. The most common forms are a small gastropod and fragments of crinoid stems. Here and there a brachiopod is observed, and other forms may be present locally.

The Cottonwood does not form a conspicuous ledge but is commonly found outcropping in smooth grassy slopes. It is therefore difficult to trace and in places can not be found through horizontal distances of a mile or more.

The distinguishing characters of the Cottonwood are its oolitic structure, its slightly greenish color, its rough weathered surface with a pimply aspect, and the general absence of the small oval limonitic bodies that characterize the Crouse and Wreford limestones. These criteria do not serve, however, to separate the two benches of the Cottonwood from each other or to distinguish them from the thin bed occurring locally 22 feet above it. This upper limestone, where observed, contains a few fossil *Myalina* and is distinctly conglomeratic, especially in a thin layer at the top of the bed. The base of the Cottonwood limestone is provisionally taken by the Geological Survey as the base of the Permian.

Crouse limestone.—The Crouse limestone lies about 140 feet above the Cottonwood and ranges in thickness from 6 or 8 feet in the northern part of the area to about 2 feet in the southern part. It is well bedded and forms very conspicuous outcrops, which generally weather in large massive slabs, especially where the limestone is yellow. A notable feature of the Crouse is an abrupt change in color laterally from a gray to a yellow phase in which for about 100 feet all the layers of the bed are consolidated into a massive bed of yellow limestone that has the appearance of a separate lenslike mass. The layers of the gray phase can be traced through the yellow phase, but there they do not form planes along which the limestone weathers as they do in the gray limestone. These features decrease in prominence toward the south, where the upper part of the main bed has a pale orange color and contains an abundance of small yellow limonitized oval bodies. Overlying the orange-colored bed in the southern part of the area is a reddish, in places conglomeratic limestone which weathers back readily and is commonly not well exposed. The limestone contains a fossiliferous layer at the base.

Wreford limestone.—The Wreford limestone occurs 112 to 119 feet above the Crouse. It is 8 to 10 feet thick in the northwestern part of the area and is made up of several layers which generally are not so massive as the Crouse. It decreases considerably in thickness to the south and west, being only 3 to 4 feet thick in T. 25 N., R. 3 E., and not more than a foot thick in places in the extreme southwestern part of the area, where the lower part of it has changed to a calcareous sandstone and locally the entire bed becomes sandy. Its color is commonly gray, but there is at the top a pale yellow or buff layer very similar in appearance to the yellow part of the Crouse. In fact, it would be exceedingly difficult to distinguish hand specimens from the two limestones. The gray portion of the bed is in places spotted with velvet-brown spots which produce brown blotches on the weathered surface. In the northern part of the area the limestone forms prominent escarpments, but in the southwestern part the sandstone above the limestone is the principal rim maker. About 5 feet above the main bed there is a thin upper bed of limestone which is commonly weathered back from the prominent ledge and covered with soil. In Kansas and in other parts of Oklahoma the Wreford is said to contain a large amount of chert, but it has no chert in this area.

Winfield limestone.—About 168 feet above the main bench of the Wreford occurs the main bed of the Winfield limestone, a du argillaceous limestone that forms a ledge about 3 to 4 feet thi nonpersistent ledge occurs 5 to 7 feet above the main one, and a ledge about 18 inches thick occurs about 14 feet below it. The b between the Wreford and Winfield limestones are principally shal which have weathered into long, gentle slopes without rock outcrops

Herington limestone.—The main ledge of the Herington limestone lies about 54 feet above the Winfield. This is a light buff-colore limestone that forms massive ledges 5 to 6 feet thick. A ledge 18 inches thick lying 7 feet above the main one does not form a continuous outcrop, and 8 feet higher there is a very local ledge 4 feet thick.

The interval between the Winfield and Herington limestones is occupied by thin-bedded red sandstones and siliceous shales. Locally a massive sandstone occurs just below the Herington.

UNEXPOSED ROCKS.

GENERAL RELATIONS.

The rocks not exposed at the surface which have been penetrated by the drill to depths of nearly 4,000 feet in or adjacent to the "west side" are shown in Plate XLV.[1] Of the five well records shown, two (columns 3 and 4) represent wells drilled in the Osage Reservation west of R. 8 E.; the other three represent wells adjacent to the "west side" on the east, south, and west. Column 4 is representative of the numerous wells drilled in the Cleveland and Boston pools and many scattering wells in Tps. 21 and 22 N., R. 7 E. From these logs it is possible to gain a fair idea of the strata that probably underlie the "west side." The logs seem to indicate that the lower sands are not so well defined west of the area described (see column 1) as they are east of it.

OIL AND GAS BEARING BEDS.

In the Cleveland pool, in T. 21 N., R. 8 E., oil is found in the Layton, Cleveland, Bartlesville, and Tucker sands. In the Boston pool, which lies mainly east of R. 7 E. but extends into sec. 1, T. 21 N., R. 7 E., and sec. 36, T. 22 N., R. 7 E., these same sands are productive, although the main yield comes from the Bartlesville. In the Section Eight pool, in secs. 8, 9, 10, 15, and 16, T. 23 N., R. 8 E., the chief oil-bearing bed is said to be the Bartlesville sand, but gas in large quantities is obtained from several shallow sands lying above the

[1] Slightly revised, on the basis of additional information obtained, from pl. 21, Bull. 686–L.

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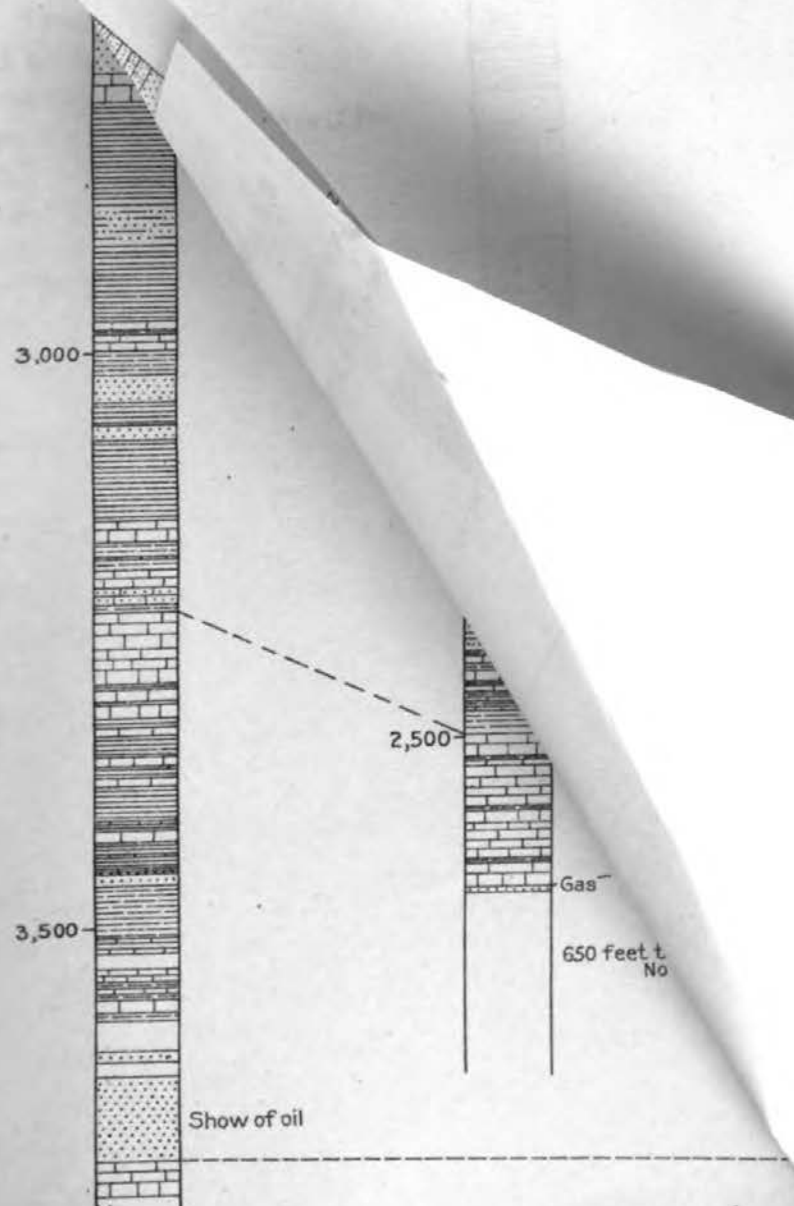


SECTIONS SHOWING DRILLERS' INTERPRET

THEIR RELATIONS TO

Layton sand. In the Pawhuska quadrangle, in the eastern part of Osage County, oil and gas are obtained at two or more horizons in the "Mississippi lime," also in the Bartlesville (here including the Tucker) sand, the "Oswego lime," sands between the "Oswego" and Big limes, the Big lime, and a sand about 100 feet above the Big lime. It is reasonably certain that some of these sands underlie the "west side," and the inference is warranted that oil and gas will be found in them where structural and other conditions favor accumulation. The Ponca City field obtains its oil and gas chiefly from shallow sands, most of which come to the surface in the "west side."

Attention is also called to the large initial production of oil recently obtained from several wells at depths of 300 feet or more in the "Mississippi lime." These include two wells in secs. 13 and 14, T. 22 N., R. 8 E., the "gusher" well in sec. 17, T. 27 N., R. 8 E., and the Mollie Miller well No. 9, in sec. 9, T. 25 N., R. 2 E., near Ponca City. Each of these wells is reported to have had a large initial daily production, amounting in some to 1,000 barrels or more. These large yields from a horizon heretofore essentially untouched in the Osage country are of great promise for the "west side," even though the Bartlesville or other productive sands of the "east side" may not underlie the entire area. The writers, therefore, reiterate the suggestion contained in the chapters of this bulletin previously published, that no test is complete until the drill has penetrated the "Mississippi lime" to a depth of at least 300 feet and that a well now obtaining its supply of oil and gas from higher horizons should not be abandoned until the "Mississippi lime" has been thoroughly tested, especially if the well is on a well-developed anticline or dome.

The probable relation of the oil and gas sands to the key beds described is shown in columns 6 and 7, Plate XLV. Lack of parallelism between strata makes it difficult to correlate beds encountered in drilling in widely separated areas. The correlations shown on Plate XLV are therefore suggestive and tentative rather than conclusive, but they are based on a careful study of the columnar sections of rocks exposed in both the western and eastern part of the Osage country and on a comparison of these sections with the logs of wells whose approximate surface horizons are known.

The correlation of the sands of the Ponca City field with the stratigraphic section of the western part of the Osage Reservation, as shown in Plate XLV, is slightly different from that suggested by Ohern and Garrett.[1] The correlation here given indicates that the

[1] Ohern, D. W., and Garrett, R. E., The Ponca City oil and gas field: Oklahoma Geol. Survey Bull. 16, p. 27, 1912.

500-foot sand of the Ponca City field is probably equivalent to one of the sands associated with the Cottonwood limestone; that the "fourth sand" is probably equivalent to the sandstone above the Stonebreaker limestone which crops out about 4 to 6 miles west of Fairfax; and that the lowest productive sand is at approximately the same position as the Elgin sandstone.

The estimated depths at which the most important oil and gas sands and also the "Oswego lime" and "Mississippi lime" will be encountered in drilling are given in the following table:

Estimated intervals, in feet, from exposed key beds to important oil and gas sands and "Oswego lime" and "Mississippi lime."

Key bed.	Layton sand.	Cleveland sand.	"Oswego lime."	Bartlesville sand.	"Mississippi lime."
Herington limestone	2,841	3,141	3,341	3,780	3,840
Winfield limestone	2,786	3,086	3,286	3,726	3,786
Base of Wreford limestone	2,621	2,921	3,121	3,561	3,621
Crouse limestone	2,509	2,809	3,009	3,440	3,509
Cottonwood limestone	2,369	2,669	2,869	3,309	3,369
Base of Neva limestone	2,259	2,559	2,759	3,199	3,259
Red Eagle limestone	2,189	2,489	2,689	3,129	3,189
Base of Foraker limestone	2,033	2,333	2,533	2,973	3,033
Grayhorse limestone	1,931	2,231	2,431	2,871	2,931
Top of Stonebreaker limestone	1,842	2,142	2,342	2,782	2,842
Cryptozoon-bearing limestone	1,717	2,017	2,217	2,657	2,717
Bird Creek limestone	1,627	1,927	2,127	2,567	2,627
Turkey Run limestone	1,575	1,875	2,075	2,515	2,575
Lecompton (?) limestone	1,490	1,790	1,990	2,430	2,490

This table gives an idea of the depth at which the productive sands of the Cleveland pool, to the southeast, and deeper sands in other productive fields in Oklahoma should be reached in any particular part of the area discussed. The figures are of course only approximations. They are based on a study of the well logs of the Cleveland, Boston, and Section Eight pools, where the relations of the productive sands to the surface key beds can be determined, and on the observed thicknesses of the rocks exposed in the "west side." The table is also based on the assumption that the interval between the key beds and the "Mississippi lime" remains constant across the "west side." If, however, as assumed by Berger,[1] the interval between the "Mississippi lime" and the "Oswego lime" (Fort Scott limestone) decreases rapidly from about the central part of the Osage Reservation westward, of course these intervals, especially those below the "Oswego lime," would not hold in the western part of the area. It is noteworthy, however, that logs of wells in the Ponca City field, lying west of the Osage Reservation, when properly adjusted to the key beds of the section of exposed rocks, coincide within reasonable limits with logs of wells east of R. 7 E., in the reservation.

[1] Berger, W. R., The relation of the Fort Scott limestone to the Boone chert in southeast Kansas and northeast Oklahoma: Jour. Geology, vol. 26, pp. 618–621, 1919.

STRUCTURE AND OIL AND GAS POSSIBILITIES.

GENERAL FEATURES.

The rocks in the area described show an average westward dip of about 40 feet to the mile, or a little less than half a degree. The westward dip is more constant here than in the eastern part of the Osage Reservation, and there are fewer deviations from the general regional structure and consequently fewer anticlines and domes.

Because of this regional westward dip, the rocks that form the surface are successively younger and higher stratigraphically toward the west. For this reason the rocks that appear at the surface in the "west side" have been eroded from most of the area farther east, and conversely, the rocks exposed in those areas lie below the surface of the "west side" and are not open to inspection. The convergences which are known to occur between these lower rocks in the "east side" have not been taken into account in drawing the structure contours for the "west side." The higher the position of the surface beds in the geologic column the more widely may they depart from parallelism with the rocks below, especially those which, like the "Oswego lime" and "Mississippi lime," and the Bartlesville sand, lie at depths of 2,000 feet or more. This lack of parallelism precludes the possibility of matching structure contours that are drawn on widely separated reference horizons, and consequently some discrepancy may appear between the contours along the common margin between the area herein described and the "east side." The structure contours shown on Plates XLIII and XLIV are drawn on the top of the Bird Creek limestone. The detailed description of structure which follows is presented mainly by township units.

TPS. 21 AND 22 N., R. 7 E.

About one-third of that part of Tps. 21 and 22 N., R. 7 E., which lies within the Osage Reservation is covered by alluvium, sand, and surficial material, which conceal the hard rocks and prevent the determination of structure by surface methods. Over the remainder of the area the regional westward dip is interrupted at several places by north and south dips which give rise to more or less prominent anticlinal noses. Slight easterly dips occur at only a few places.

Boston pool.—The Boston pool lies mainly in T. 21 N., R. 8 E., but extends into the E. ½ sec. 1, T. 21 N., and the southeast corner of sec. 36, T. 22 N., R. 7 E. So far as can be determined from surface evidence, that part of the pool lying in this area occupies the western limb of the fold, whose crest is farther east. The productive area, which is leased mainly by the Gypsy Oil Co., seems to be pretty well defined by several dry holes drilled on the north, west, and southwest and appears to be confined to the E. ½ sec. 1, T. 21 N., and the SE. ¼ sec. 36, T. 22 N. So far as can be determined from the well records none of the dry holes drilled have entered the "Mississippi lime," and there is therefor still a possibility that oil may be obtained from this formation farther down the slope than the present productive area extends. Most of the oil obtained comes from the Bartlesville sand. The initial daily production of the wells is reported to range from 20 to 5,000 barrels and to average about 350 barrels.

Gas anticline.—The principal axis of the Gas anticline extends southwestward from the northeast corner to the west quarter corner of sec. 25, T. 22 N.; a minor axis crosses the NE. ¼ sec. 26. The axis pitches southwestward about 40 feet across sec. 25 and flattens somewhat across sec. 26. The north and south limbs of the fold have well-defined dips through distances of half a mile or more. There is a very slight east or northeast dip near the west side of the NW. ¼ sec. 25, but it is not sufficient to close a contour. The outline of the fold is based on elevations on the Turkey Run and Lecompton (?) limestones, both of which are well exposed and furnish good key beds. Several gas wells have been brought in along the crest of this anticline in sec. 25, and at least three dry holes have been drilled on its north and west slopes in sec. 26. The gas in the producing wells is obtained from a sand about 50 feet below the base of the "Oswego lime," called in this area the Peru sand, but at a different horizon from the Peru sand in other areas. A log of one of these wells is shown in column 4, Plate XLV. In this well, which begins at about the base of the Lecompton (?) limestone, the Layton sand was reached at 1,500 feet, the Cleveland at 1,790 feet, the "Oswego lime" at 1,990 feet, and the gas sand ("Peru") at 2,165 feet. A log of one of the group of three wells in the W. ½ sec. 25 shows a similar record. Apparently none of these gas wells were drilled to the Bartlesville sand, and the fact that only gas was obtained does not preclude the probability of finding oil at greater depths, either in the Bartlesville sand or in the "Mississippi lime." In fact, the chances are good that oil will be found on this fold in these lower beds. The dry holes on the north and west slopes of the anticline may or may not be adequate tests; no record of them is available by which to judge their merits. Their dry condition may be due to failure to drill deep enough—by which is meant 300 feet more into the "Mississippi lime"—or to their being located too low on the slopes of the fold, although two of them, that at the northeast corner of sec. 26 and that about 1,000 feet south of the north quarter corner, are fairly well located with reference to the structure. Further development of the deeper sands should be undertaken on this anticline.

Minor folds.—A low nose extends southwestward from the SW. ¼ sec. 34, T. 22 N., to the center of sec. 4, T. 21 N., or perhaps farther.

This fold pitches gently to the southwest and has gentle north and south dips. It terminates on the northeast in a broad structural flat or terrace, which in turn is terminated farther northeast by a closed depression. The highest point on the terrace is nearly 10 feet above the center of the depression, so that there is a slight northeast dip, though not enough to be indicated by the closing of a contour. The fold is, therefore, to be regarded as possible oil and gas territory and is sufficiently well defined to warrant the drilling of at least one good test well, which should be located somewhere along a line drawn from a point about 1,000 feet west of the east quarter corner of sec. 34 to the southwest corner of the section. In that area the crest of the fold is capped by sandstones and shales lying above the Bird Creek limestone, which is estimated to lie about 2,567 feet above the Bartlesville sand. A dry hole has been drilled on this fold near the east quarter corner of sec. 34, a little east of the highest point on the terrace. No record of this well has been obtained, but it probably did not penetrate the "Mississippi lime," as all drilling in this area has stopped short of that limestone. A better location for the well would have been at least 1,000 feet farther west.

Another minor fold enters R. 7 E. from the east of the northeast corner of sec. 13, T. 22 N., and occupies the NE. ¼ sec. 13 and a small part of sec. 12. Unless the fold has larger dimensions in the area to the east, a report on which is now in preparation by Robert H. Wood, it may be too small to be of economic importance.

A third fold of minor importance extends westward from the NE. ¼ sec. 2, T. 22 N., to the center of sec. 3. The fold is terminated on the east by a shallow depression which produces an eastward dip of a few feet. The north and south dips are gentle, and the axis of the fold pitches west at the rate of about 40 feet in the first mile. This fold is not regarded as of first importance, but if the more pronounced folds in the township to the north should prove to be productive this fold would at least fall in the category of possible oil and gas territory and would probably justify the drilling of at least one test well, which should be located on the crest of the fold, probably along the south line of the NW. ¼ sec. 2.

T. 23 N., R. 7 E.

The regional westward dip across T. 23 N., R. 7 E., amounts to about 50 feet to the mile, which is considerably higher than the average regional dip in the Osage Reservation. This unusually high dip is the result of rather pronounced folding in the eastern part of the township, with consequent steepening of the beds adjacent to the folded area on the west. In the southwest quarter of the township there is about 6 square miles in which there are no exposures of hard rock and in which, therefore, the structure can not be worked out from surface observations.

The folded area in the eastern part of the township, forming a crescent stretching from the northeast to the southeast corners, probably represents one major line of folding on which are superimposed three local domes. However, for the sake of clearness and facility in description, it will be described as three independent units—the Upper and Middle Bug Creek domes, and the Lower Bug Creek anticline.

Upper Bug Creek dome.—The Upper Bug Creek dome occupies all of sec. 12 and an adjoining portion of sec. 13, with a long spur projecting northward across the E. ½ sec. 1. The dome as thus outlined is merely part of a larger fold which covers several square miles in the township to the east and on which lies the productive Section Eight pool. To the north the dome is connected by a narrow saddle with the Rainbow anticline, and to the southwest it may be continuous with the Middle Bug Creek dome. On the west and northwest there is a broad unbroken area of westward-dipping beds from which an abundant supply of oil and gas could have been drained if they were present in the rocks. The crest of the dome lies about at the center of the S. ½ sec. 12, and from this point the rocks dip in all directions—gently to the north, east, and south, and steeply to the west, northwest, and southwest. The westward dip amounts to 120 feet in the first mile; the eastward dip probably amounts to about 15 feet but is not accurately determinable because of lack of exposures of dependable key beds. The outline of the dome was determined chiefly by elevations on the Turkey Run and Bird Creek limestones. On account of the productive area near by on the east this dome affords excellent prospective territory in which to drill for oil and gas. The best place for a test well is about the center of the S. ½ sec. 12.

Middle Bug Creek dome.—The Middle Bug Creek dome occupies practically all of sec. 23 and parts of secs. 13, 14, and 24. On the northeast it is separated from the Upper Bug Creek dome by a narrow belt of steep dips which serves as a step from the higher to the lower level. On the south it is separated by a low, narrow saddle from the Lower Bug Creek anticline. To the west and southwest the westward dip, amounting to 100 feet in the first mile, is unbroken, and up this slope oil and gas would probably migrate to the crest of the dome, where they would be entrapped by the reversal of dip. This reversal is gentle, and from the crest of the dome, about 700 feet south and 300 feet west of the center of sec. 23, amounts to about 20 feet on the northeast and 30 feet on the southeast. The exposure of the Turkey Run limestone around the upper slopes of this fold and the Bird Creek limestone lower down furnish good key beds from which to obtain data for the deciphering of the structure. The fold is regarded as good prospective oil and gas territory. A test hole should be located near the center of sec. 23.

Lower Bug Creek anticline.—That part of the Lower Bug Creek anticline lying in this township is a triangular area whose axis trends northwestward from the margin of the township to the north-central part of sec. 26; it thus occupies parts of secs. 25, 26, and 36 in this township and extends eastward an undetermined distance. The relation of this fold to the Middle Bug Creek dome has already been pointed out. On the south the beds dip steeply to a flat and shallow syncline near the township boundary. The westward dips are unbroken so far as they are determinable, and like the folds above described, this one has a good catchment area in that direction. The crest of the fold is sharp and well defined in sec. 26 but broadens out and partakes more of the nature of a broad flat, on which there are minor local protuberances, in secs. 25 and 36. Within this township the fold exhibits no well-defined or appreciable eastward dip. Its shape and extent, like those of the folds described above, were determined from elevations on the Turkey Run and Bird Creek limestones, supplemented by elevations on the sandstones between them. The fold is regarded as favorable prospective oil and gas territory. A good location for a test well would be near the northwest corner of sec. 36, or in the W. ½ SE. ¼ sec. 26.

Upper Sycamore dome.—The Upper Sycamore dome lies principally in secs. 9 and 16 but extends westward for a short distance into secs. 8 and 17. The dome is cut off on the east by a normal fault dipping 60°–75° E. and trending northwest and north. The trace of the fault at the surface is about 2 miles long and markedly curved. This curving is probably due, at least in large part, to the combined effects of dip of the fault plane and the topography of the ground, though there may be some actual curving in the fault plane. The maximum vertical displacement caused by the fault is about 70 feet. On its east or downthrow side the beds dip steeply toward it, producing a closed depression about 70 feet deep. North of this depression the beds dip away from the fault and give rise to a small dome about 20 feet high closing against the fault. On the west of the fault the dome has about 70 feet of dip, nearly 50 feet of which closes against the fault. On the assumption that the oil sands are sealed along the fault plane so as to prevent the escape of oil and gas, its effect on their migration and accumulation would be the same as that of an eastward dip of the strata—that is, the fault would form an obstruction to the further eastward migration of the oil and gas and cause them to accumulate in the crest of the dome. If this assumption is true the dome would furnish an excellent reservoir for the accumulation of oil and gas, and there is a large drainage area to the west from which these substances might have been gathered. The extent of the fault underground is of course unknown. It may largely die out in the Cherokee shale before reaching the Bartlesville sand; on the other hand, it may possibly increase in magnitude with depth, and the amount and direction of its dip and strike may also change. The best locations for test wells would be along a line drawn from a point 1,500 feet south of the northwest corner of sec. 16 through the north quarter corner of the same section to the fault plane. The first well should be located near the fault. If gas and no oil is obtained along the crest of the fold, tests for oil should be made farther down the slope. As the fault dips eastward, wells drilled at a considerable distance east of the fault trace as it appears at the surface would pass through the fault plane before reaching the oil sands, penetrating them on the west side of the fault, where they would yield oil and gas if these substances are present. On the other hand, wells entering the pay sands east of the fault plane would have very little chance of obtaining oil or gas. The contours are drawn to the trace of the fault as it appears at the surface rather than to its theoretical position at the datum plane, as the data at hand are not sufficient to determine the position of the fault below the surface.

Gas and oil sands.—No wells have been drilled in T. 23 N., R. 7 E., but two dry holes have been put down in the northern part of the township to the south. However, the Section Eight pool, in secs. 8, 9, 10, 15, 16, and 17, T. 23 N., R. 8 E., and the Boston pool, partly in sec. 1, T. 21 N., R. 7 E., and sec. 36, T. 22 N., R. 7 E., furnish many well logs, which with the logs of a few other scattered wells afford a means of forecasting the probable oil and gas sands to be encountered in the area under discussion. There are about a dozen sands that have yielded oil or gas in these wells.

The Bartlesville sand is the main producing sand of the adjacent territory, but two wells in secs. 13 and 14, T. 22 N., R. 8 E., lately obtained large initial yields from a recently discovered oil sand about 300 feet below the top of the "Mississippi lime."

Below is an estimate of the depth below the Turkey Run limestone at which the several sands should be encountered. The Turkey Run limestone is a prominent though thin lime, well exposed in much of the township under discussion.

It will be noted that the drillers in the Boston pool have called a sand below the "Oswego lime" the "Peru sand." Northeast of this township, however, the name Peru sand is used to indicate a sand above the "Oswego lime" and below the Big lime. This inconsistency is probably due to the fact that the Big lime is not as well developed to the south as to the northeast.

Estimated depth of oil and gas sands below the Turkey Run limestone in T. 23 N., R. 7 E.

Depth below Turkey Run limestone.	Remarks as to conditions in wells to east and south.
Feet.	
650	Sand, which shows a small amount of gas in many wells.
740	Sand giving as much as 1,000,000 feet of gas in some wells.
850	Sand giving as much as 1,000,000 feet of gas in one well, small amount in several wells.
900	Sand giving as much as 3,000,000 feet of gas in some wells.
955	Sand giving as much as 25,000,000 feet of gas in one well and much gas in many wells.
1,120	Sand giving 2,000,000 feet of gas in one well.
1,260	Sand giving 8,000,000 feet of gas in one well and smaller quantities in several wells.
1,310	Sand giving 2,500,000 feet of gas in one well.
1,475	Do.
1,575	Layton sand; some gas, little oil.
1,875	Cleveland sand; gas, oil.
2,075	"Oswego lime."
2,275	"Peru sand" of Boston pool; little gas, oil.
2,460	Skinner sand; oil.
2,515	Bartlesville sand; main pay oil, some gas.
2,775	Tucker sand; little oil.

The Bartlesville sand and the bed about 300 feet below the top of the "Mississippi lime" will probably be the main oil sands, although some of the higher sands may produce oil in commercial quantities. Gas will probably be found in the higher sands.

T. 23 N., R. 6 E.

The regional westward dip in T. 23 N., R. 6 E., averages about 33 feet to the mile. Local deviations from this general westward inclination gave rise to north and south dips, but with the exception of a slight eastward dip on the Sycamore anticline, no reversals or eastward dips occur in that part of the township where the exposures afford an opportunity for working out the structure. As will be observed from the map (Pl. XLIII), however, about one-third of the surface of the township is covered by loose sand, soil, and alluvium, which conceal all the hard-rock formations and prevent the determination of structure in these areas from surface observations.

In addition to the Lower Sycamore anticline, the township contains a few noses which are briefly described. They are not of sufficient importance to be recommended for drilling in wildcat territory, but if future development demonstrates the existence of oil and gas in the better-defined anticlines and domes in adjacent areas, some of these noses might be worth testing.

Lower Sycamore anticline.—The Lower Sycamore anticline occupies the SE. ¼ sec. 35 and the S. ½ sec. 36, and also extends south into secs. 1 and 2, T. 22 N. The north and south dips amount to at least 20 feet, and there is a slight east dip but not sufficient to close a contour, the axis being nearly horizontal for more than half a mile. Because of its isolation with respect to other well-defined folds the anticline is well situated for the accumulation of oil and gas. It is not recommended for drilling, however, until other more favorable anticlines and domes in the western Osage country have been tested. The highest point on the fold is about 1,000 feet east of the southwest corner of sec. 36, and this would therefore be the most favorable location for a test well. The fold is capped by a heavy sandstone that overlies the highest limestone bed of the Stonebreaker limestone. By reference to the table on page 288, the depth to the oil and gas bearing sands may be approximately determined.

Minor folds.—A nose, narrower but somewhat longer than the Lower Sycamore anticline, extends from the SW. ¼ sec. 24 to the NW. ¼ sec. 26. The complete details of this fold can not be worked out because on its southern limb the rocks are concealed by sand. On the southwest the nose is limited by steep dips, and on the northeast it merges into a narrow terrace.

Another nose occupies the N. ½ sec. 1, but the north and south dips on it are gentle and do not exceed 20 feet.

There also appears to be a small nose with a southwest trend in the N. ½ sec. 6, but the details of the fold are indeterminable because of lack of exposures. Its outline is based on elevations on a limestone which crops out along the east side of the river, and on evidence obtained in the township adjoining on the north. This fold seems to be broader and to have a steeper inclination of its axis than any of the other folds here described.

Besides the larger noses described there are several smaller ones which are too small to merit individual description and are probably also too small to be of economic interest.

TPS. 23 AND 24 N., RS. 3 TO 5 E.

In Tps. 23 and 24 N., Rs. 3 to 5 E., there is a greater deviation from the regional westward dip common in the Osage Reservation than in any of the other townships shown on Plate XLIV. This deviation from the regional dip gives rise to several anticlines and domes and a number of minor folds. The best-defined anticlines and domes offer structurally favorable places for the accumulation of oil and gas. Some of these folds are small and are probably not worth testing unless the larger ones prove to contain oil and gas in commercial quantities. As in other parts of the field there is a belt along Arkansas River ranging from less than half a mile to several miles in width in which the hard-rock formations are covered by alluvium, sand, or surficial material. In these areas the structure can not be worked out from surface observations. This belt is especially wide in R. 3 E., where it includes the greater part of that portion of Tps. 23 and 24 N. lying within the Osage Reservation. In

T. 23 N. numerous water wells put down as much as 2 miles back from the present river channel have penetrated unconsolidated river sand to a depth of about 90 feet before reaching bedrock. This suggests that the river channel formerly extended considerably farther north than at present. Part of this area is in a direct line north of the Otoe anticline, which is producing gas and, according to reports, some oil on the south side of the river in T. 23 N., R. 3 E. It may well be, therefore, that in this area of concealed hard-rock formations there are structural features favorable for the accumulation of oil and gas. A detailed study of the outcrops in the bluffs immediately south of the river would throw some light on the conditions north of the river.

Dogy dome.—The Dogy dome occupies part of secs. 7 and 18, T. 24 N., R. 5 E., and secs. 12, 13, and 24, T. 24 N., R. 4 E. It covers an area of more than 2 square miles and has a maximum eastward dip of nearly 20 feet, with a closure of 10 feet over an area approximately half a mile wide and 1½ miles long, trending northeastward. To the northwest, west, and southwest the dip is very steep, ranging from 50 to 70 feet in the first half mile and then gradually decreasing. To the north there is a long space extending from the center of sec. 7, R. 5 E., to about the center of sec. 6, which offers possibilities for oil accumulation. To the south the dip is apparently not so steep, but little information regarding the structure can be had in that direction because of lack of exposures of hard rock in the river valley. The highest point on the fold is approximately at the northeast corner of sec. 13, T. 24 N., R. 4 E., and this would therefore be the most favorable place for a test well. Should gas be obtained here other tests should be made for oil farther down the west slope.

The surface rock over the crest of the fold is the sandstone immediately overlying the Neva limestone. The depth to the "Oswego lime" and "Mississippi lime" is therefore about 2,780 and 3,280 feet, respectively.

East Belford dome.—The East Belford dome lies in the SW. ¼ sec. 28 and the SE. ¼ sec. 29, T. 24 N., R. 4 E. It has an eastward closure of about 10 feet over an area of about half a mile. The details of the fold were determined mainly by elevations on a prominent sandstone ledge lying about 70 feet above the Crouse limestone. The highest point on the fold lies about 1,500 feet north of the southwest corner of sec. 28. From this point the rocks dip gently to the north, south, and east but more steeply to the west. Immediately north of the fold there is a broad, shallow syncline. This dome is so small that it may not have had much effect in inducing oil accumulation. If, however, the Dogy dome, about 4 miles to the northeast, proves to be productive, the prospects for obtaining oil in the East Belford dome would be increased. To test the fold a hole should be drilled not more than 1,500 feet north of the southwest corner of sec. 28. At this place the depth to the "Mississippi lime" is estimated to be about 3,580 feet.

West Belford dome.—The West Belford dome is a small fold occupying the SE. ¼ sec. 30 and the NE. ¼ sec. 31, T. 24 N., R. 4 E. It has an eastward dip of about 15 feet and a closure of 10 feet over about a quarter of a square mile. The dip to the north and south amounts to 15 or 20 feet, and that to the west to about 30 feet in the first half mile. The outline of the fold was determined by elevations on the Wreford limestone and the prominent sandstone overlying it. The fold is small, but with an eastward dip of 10 to 15 feet and a large gathering ground it is well worth testing. The crest of the fold extends nearly due north through a point about 1,500 feet west of the southeast corner of sec. 30. A test hole should be located along the crest not more than 1,000 feet either north or south of the line between secs. 30 and 31. The sandstone immediately above the Wreford limestone covers the crest of the fold. The depth to the "Oswego lime" is therefore about 3,135 feet and to the "Mississippi lime" about 3,635 feet.

Sand Creek anticline.—The Sand Creek anticline is a northward-trending fold occupying parts of the four sections cornering on the intersection of Tps. 23 and 24 N., Rs. 3 and 4 E. Details of the west limb of the fold can not be determined because of lack of exposures. The structure of the remainder was worked out from elevations on the Wreford limestone, the thin limestone about 20 feet above the Wreford, and the sandstones immediately underlying these two limestones. The east limb of the fold is cut by a northwestward-trending fault, the extent of which can not be accurately determined. The maximum vertical displacement caused by the fault seems to be about at the center of sec. 6, T. 23 N., R. 4 E., where the Wreford limestone has been dropped down (relatively) on the west side about 50 feet. From this point the amount of displacement decreases both to the north and south. It seems to be only 15 or 20 feet in the SW. ¼ sec. 31, T. 24 N., R. 4 E. The Sand Creek anticline pitches south and shows no closure on the north, but near the south end there is a slight structural depression in its crest, south of which there is a small local dome that has a closure of about 8 feet. This fold is well situated, and although it has no northern closure it should afford good opportunity for the accumulation of oil and gas. Good locations for test wells would be anywhere within the area closed by the —20-foot contour on the south end of the fold or along a line 500 to 700 feet west of the line between Rs. 3 and 4 E. to a point not more than 2,000 feet north of the corner between Tps. 23 and 24 N. At these places the depths to the "Oswego lime" and "Mississippi lime" should be about 3,150 and 3,650 feet, respectively.

Minor folds.—A long northwestward-trending nose lying about 1½ miles southwest of Fairfax extends diagonally across secs. 13, 14, and 24, T. 24 N., R. 5 E. The exact outline of this fold can not be determined, because a part of it lies in the valley of Arkansas River, where there are no exposures of hard rock. In the bluffs skirting the river on the east the rocks dip northwest at an average rate of 60 feet to the mile. Work on the opposite side of the river failed to disclose any corresponding southward dips. In fact, the rocks rise more or less regularly from the northernmost exposures in the bend of the river to the south side of the township. These exposures, however, are about 1½ miles away from those exhibiting the steep dips on the east side of the river, and there is thus room for a reversal of structure in the river valley. From the evidence available the axis of the fold seems to pitch northwest, being parallel to and probably coincident with the bluffs along the east side of the river. It may well be, however, that the axis of the fold trends more nearly west, and, if so, the northwest dips exhibited along the river bluff represent only a part of the northwest limb of the fold. On this assumption the greater part of the fold lies in the river flat and the north and south dips are 50′ or 60′ greater than those indicated on the assumption of a northwest trend to the fold. In either event there is no east dip, and the fold, therefore, does not rank as one of the first importance. If its axis trends west the fold is of considerable importance, even though it has no eastward dip. A good location for a test well on this fold would be about the center of the SE. ¼ sec. 14, on the flats on the east side of the river.

A long nose trending southwestward extends more or less uninterruptedly from the northeast corner of sec. 11, T. 24 N., R. 4 E., to the valley of Arkansas River at the northwest corner of sec. 21. The trend of this nose is approximately parallel to that of the Dogy dome. It has no pronounced flats, steepenings, or saddles along its crest that would seem to offer favorable conditions for local accumulations of oil or gas, and it is probably not sufficiently pronounced to have induced large accumulations through its entire length. It is therefore not regarded as promising oil or gas territory.

There is also a small nose trending east along the line between Tps. 24 and 25 N., R. 4 E. The amount of north and south dip here is very slight, and it is probably not sufficient to have induced the accumulation of oil and gas.

T. 25 N., R. 4 E.

The rocks exposed in T. 25 N., R. 4 E., show a gradual westward dip. This dip is the normal regional dip of the strata, which in the western Osage country averages about 40 feet to the mile. There is no distinct anticlinal or dome structure in the exposed strata of this township, but a slight variation from the normal westward dip occurs in the center of the township, in secs. 15, 16, 21, and 22, where there is a minor buckling of the strata. Just south of the center there is a structural flat or terrace. In the Appalachian and Gulf coast oil fields and locally in the Mid-Continent field such a nose or terrace induces the accumulation of a minor pool of oil; but the prospects of obtaining oil in this area on such structural features is not favorable enough to warrant a test at present. It might be justified, however, at some time in the future when the scarcity of oil would necessitate the drilling of the less favorable areas. For such a possibility it would appear that in the whole township the two best places to drill would be in the southeast corner of sec. 16 and in the NE. ¼ sec. 34. To reach the "Mississippi lime" a well would have to be drilled about 3,600 feet in this area.

T. 25 N., R. 3 E.

The structural geology of T. 25 N., R. 3 E., as shown on Plate XLIV, is based solely on the beds exposed at the surface. These beds dip west about 40 feet to the mile, showing the westward dip normal to this portion of Oklahoma.

Alluvium and river sands have prevented geologic mapping in the south tier of sections in T. 25 N., R. 3 E., and the portion of T. 24 N., R. 3 E., lying north of Arkansas River. Rocks are exposed in part of T. 25 N., R. 2 E., east of the river, where only west dips are indicated. Few rock exposures occur south of the river in T. 26 N., R. 3 E., but on the map dotted contours are shown connecting the areas in T. 25 N., R. 3 E., mapped during the present investigation with those north of the river in T. 26 N., R. 3 E., as mapped by Trout.[1] These contours indicate a westward-pitching syncline extending across secs. 34, 35, and 36, T. 26 N., R. 3 E., and secs. 1 and 2, T. 25 N., R. 3 E. A nose is also indicated extending from the northeast into secs. 4, 3, and 2, T. 25 N., R. 3 E., where there is some possibility that oil may be found.

Gentle shale slopes without rock outcrops preclude mapping the structure in some portions of T. 25 N., R. 3 E., but these areas are small and dotted contours have been extended across most of them. The greater part of the township with its westward-dipping beds offers little encouragement to the oil prospector. The most promising locality for the production of oil in the entire township is to be found in the W. ½ sec. 20 and the E. ½ sec. 19, where a very distinct flat-topped nose occurs. The most favorable location for a test well lies in sec. 19 about 1,000 feet west and 1,500 feet north from the southeast corner of the section.

[1] Oklahoma Geol. Survey Bull. 19, pt. 2, p. 269, 1917.

ADJUSTMENTS IN PORTIONS OF T. 25 N., R. 5 E., AND T. 24 N., RS. 6 AND 7 E.

Additional information acquired while mapping the area on which this report is based make slight adjustments necessary along the margin of the area adjoining on the north and east, represented on Plates XXII and XXIII of Bulletin 686–L. The most important of these adjustments occur in the west half of T. 25 N., R. 5 E., the southwestern part of T. 24 N., R. 6 E., and the southeast corner of T. 24 N., R. 7 E. These corrections and others of minor importance are shown on Plates XLIII and XLIV.

In T. 25 N., R. 5 E., the effect of the revision is to accentuate slightly the nose trending westward from the central part of the township.

In T. 24 N., R. 6 E., the data at hand show that in place of the Lower Salt Creek anticline there is merely a very small westward-trending nose of little significance with respect to the accumulation of oil and gas.

In T. 24 N., R. 7 E., the outline of the Rainbow anticline is slightly modified. As the anticline was incorrectly named in the previous report the description is reproduced here under the proper title. The Rainbow anticline occupies parts of secs. 25 and 36, T. 24 N., and extends eastward into the Pawhuska quadrangle. That part of the fold lying in the "west side" was outlined by elevations on the Bird Creek limestone, which shows north, south, and west dips. The anticline has a fairly good gathering ground and is regarded as affording good opportunities for the accumulation of oil and gas. The highest part of the fold and therefore the best place for a test well is probably about the center of the SE. ¼ sec. 25.

T. 27 N., R. 10 E.

By Heath M. Robinson and R. V. A. Mills.

INTRODUCTION.

T. 27 N., R. 10 E., occupies a position in the northeastern part of the Osage Reservation that is precisely shown in figure 1 of this report. Bartlesville, the nearest and most accessible town having good railroad facilities, is about 12 miles east and 2 miles south from the southeast corner of the township. At the time of the field examination the Atchison, Topeka & Santa Fe Railway system was building a branch line from Caney, Kans., to Pawhuska, Okla., which traverses this township, as shown on Plate XLVI. When this road is completed it will place railroad facilities much closer to the developed properties in this township. Although the roads between the oil fields in this township and Bartlesville are rough, owing to the hauling of heavy loads to and from the oil fields, they are constantly used by automobiles, motor trucks, and other vehicles. Rock and Buck creeks supply most of the water used in the boilers connected with the oil industry. The township has a maximum relief of about 250 feet, and most of it is wooded. Rock Creek roughly bisects the township and, because of the rough topography along its course, presents a rather formidable barrier for transportation of heavy loads between the eastern and western parts of the township.

The field work on this township was done by R. V. A. Mills and Heath M. Robinson, geologists, assisted by Lewis Mosburg and Willard Miller, instrument men. The territory each geologist covered in the field is outlined in a sketch on Plate XLVI. All the office work on this report was done by Mr. Robinson, who is responsible for the statements and conclusions herein presented.

A telescopic alidade and a 15 by 15 inch plane table were used in mapping the structure of the township. The elevations used were controlled by a system of triangulation which was checked with the Government bench marks previously established by the United States Geological Survey in this township.

STRATIGRAPHY.

EXPOSED ROCKS.

GENERAL CHARACTER.

The rocks exposed in T. 27 N., R. 10 E., are of middle Pennsylvanian age and aggregate about 500 feet in thickness. Shale constitutes the greater part of the sediments, sandstone is next in vol-

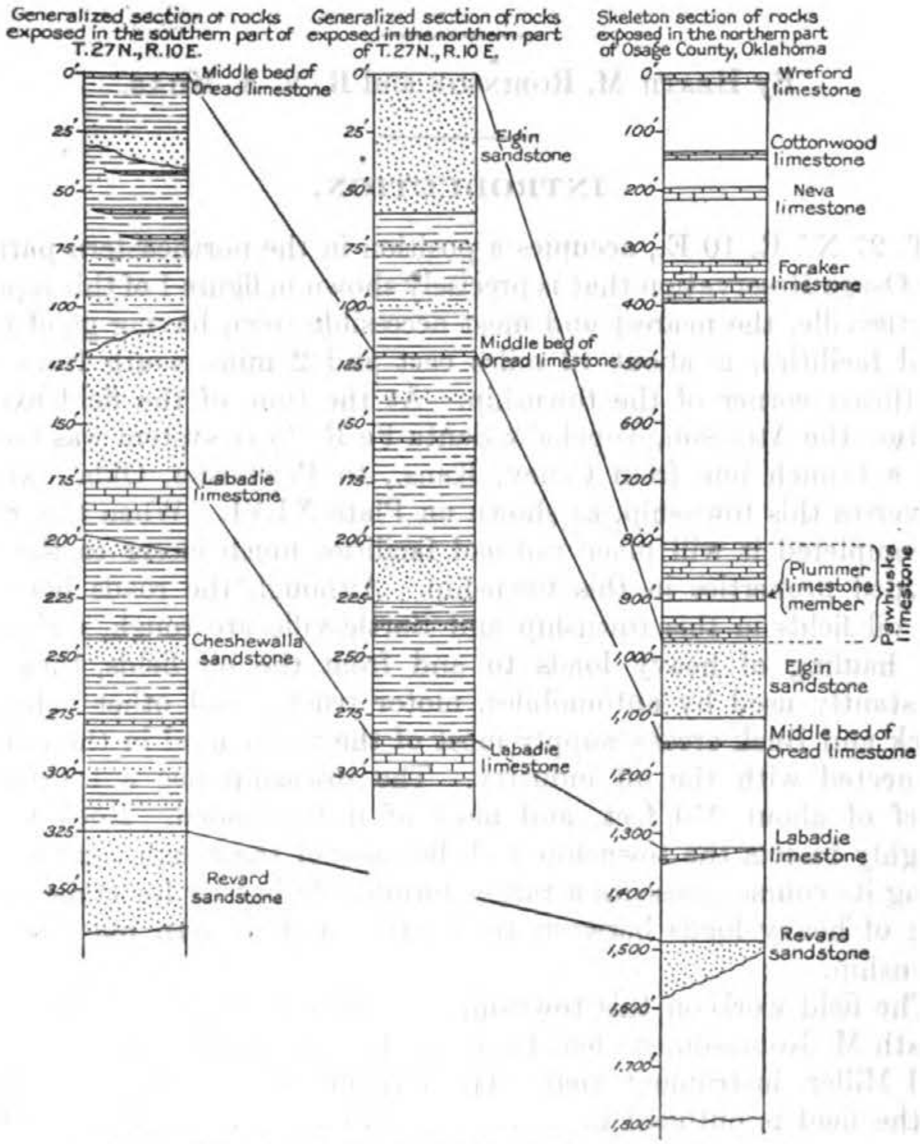


FIGURE 44.—Stratigraphic sections of rocks exposed in T. 27 N., R. 10 E.

ume, and the remainder of the section, a very minor amount, is made up of limestone. Although the limestones constitute only a small fraction of the total rocks exposed, they are to be classed as among the most important key beds used in mapping the structure of the township. Figure 44 shows three sections—a generalized section of the rocks exposed in the southern part of T. 27 N., R. 10 E.;

a generalized section of the rocks exposed in the northern part of the township; and a generalized skeleton section of the rocks exposed in the northern part of the Osage Reservation, with correlation lines indicating the relative position of the exposed rocks in T. 27 N., R. 10 E., as compared with the larger section. As this report is strictly economic in character, the description of the stratigraphy will be confined to those beds which were found to be useful in mapping the structure of the township. These beds are called key beds, and if the geologist who later does field work here identifies these key beds, he will not only be able to establish his position in the stratigraphic column but will save time by using those beds which are the most persistent and can be most satisfactorily followed.

KEY BEDS.

Middle bed of the Oread limestone.—A bed regarded as the stratigraphic equivalent of the middle bed of the Oread limestone of Kansas is overlain by about 60 feet of shales interbedded with a few thin sandstones, which, in turn, are overlain by a thick series of sandstones called the Elgin sandstone. The outcrop of the middle bed of the Oread limestone is graphically shown on Plate XLVI. As its outcrop is generally unwooded and hence easily traceable, and as its peculiar characteristics make it easy to identify in the field, it was found to be one of the best key beds in the township. It rarely exceeds 2 feet and generally was found to be a little over 1 foot in thickness. It is interbedded with a blue-gray shale and in the southern part of the township is separated by about 25 feet of shale from a well-developed sandstone below it. The limestone is steel-gray on fresh surfaces but weathers to a dirty yellow. It is dense and fine grained, contains a few *Fusulina,* and is overlain in some places by a finely conglomeratic limestone which at first glance looks somewhat like an oolite. This conglomeratic limestone is very characteristic and is not likely to be confused with any other bed in the section.

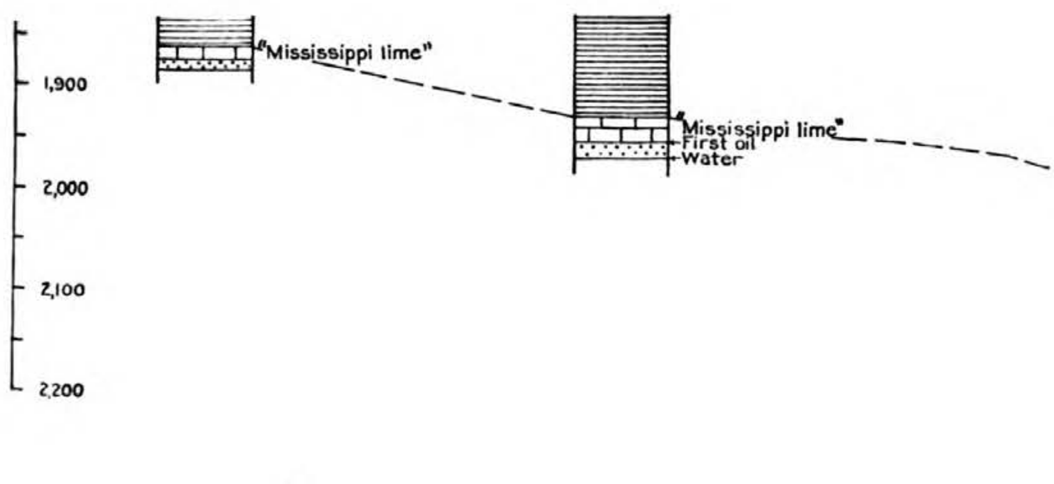
Labadie limestone.—The Labadie limestone is below the middle bed of the Oread limestone and is separated from it by about 170 feet of shales and sandstones. Figure 44 shows that the beds in this interval in the northern part of the township are different in character from the corresponding beds in the southern part. The outcrop of the Labadie limestone is graphically shown on Plate XLVI. In the northeastern part of the township this limestone is directly overlain by shale, the outcrop is unwooded, and it forms prominent ledges which can be very easily followed. In the south-central part, however, it is overlain by a thick massive sandstone, which also forms ledges and is wooded, and consequently the limestone is not so prominently exposed as in the northeastern area. The Labadie limestone is between 15 and 20 feet thick in most of the exposures in this township. The major body of the limestone is gray on fresh and weathered surfaces, but in some localities the weathered surface of the upper part has a rich cinnamon-brown color that is probably due to a high iron content. The limestone commonly weathers into large rectangular-shaped blocks a foot or so across and only a few inches thick. The bed is not abundantly fossiliferous, but in many outcrops fossils may be found.

Cheshewalla and Revard sandstones.—The outcrops of the Cheshewalla and Revard sandstones are confined to a small area in the southeastern part of this township, and consequently these beds were not found to be particularly useful in mapping the structure. However, the upper shale contact of both of these sandstones can be followed beyond the limits of this township, so it is known that they are somewhat persistent. Both of the sandstones are wooded where exposed at the surface, and in general they are very much alike in their physical characteristics.

ROCKS NOT EXPOSED.

Most of the information regarding the rocks below the surface in T. 27 N., R. 10 E., is derived from the records of the wells that have been drilled for oil and gas in this township. As the regional dip of the beds in this part of Oklahoma is toward the west, the more persistent beds described in the well logs crop out farther east, where they may be studied. About 130 well records were available in working up the table of well data given on pages 325-327, and a few of the more representative of these well records are shown on Plate XLVII. Plate XLVII also shows the relation of the subsurface beds to the exposed and unexposed rocks in the southern part of the township. The strata between the middle bed of the Oread limestone and the "Mississippi lime" have an aggregate thickness of about 2,150 feet, the upper 350 feet of which is exposed in this township. The rocks between the surface beds and the "Mississippi lime" are made up of shale, sandstone, and limestone; shale occupies about three-quarters of the section, sandstone about 15 per cent, and limestone about 10 per cent. As a rule these rocks do not "cave" enough to necessitate the use of a rotary drill, so it is a universal practice in this township to use cable tools in drilling for oil and gas. In most of the available well logs certain prominent beds are recorded, and on Plate XLVII the correlations of some of these beds, as shown in representative logs, are indicated by dashed lines. These principal subsurface beds are briefly described below.

A limestone called the Little lime is the first prominent limestone below the surface that is generally recognized by the drillers. In


"Mississippi lime"
"Mississippi lime"
First oil
Water
1,900
2,000
2,100
2,200

the southern part of the township it is about 1,450 feet below the middle bed of the Oread and about 1,280 feet below the top of the Labadie limestone. The rocks between the surface and the Little lime constitute a series of interbedded shales and sandstones, with shale constituting by far the greater part of the section. The average thickness for the Little lime given in the well logs from the southern part of the township is about 20 feet.

After drilling through the Little lime the bit usually encounters about 75 feet of shale, interbedded in some places with sandstone, before reaching the top of the so-called Big lime. The sandstone recorded in this 75-foot interval is in certain areas an important reservoir for oil and gas, but the bed is lenticular and is not recorded in many of the logs from the southern part of the township. The Big lime has an average thickness of about 70 feet, and in some records it is shown to have a shale parting 5 to 10 feet thick. It is tentatively correlated with the Oologah limestone, which crops out between 30 and 40 miles east of this township.

A limestone known as the "Oswego lime" lies below the Big lime and is separated from it by about 80 feet of shale. In some of the records a sandstone is shown interbedded with this shale member. The "Oswego lime" has an average thickness of about 70 feet, which includes, in some of the sections, partings of shale 5 to 10 feet thick. It is generally believed to be the stratigraphic equivalent of the Fort Scott limestone, which crops out about 50 miles east of this township.

A sandstone known by the drillers as the Bartlesville sand occupies a position in the stratigraphic section about 245 feet below the base of the "Oswego lime." The interval between the "Oswego lime" and the Bartlesville sand is made up largely of shale interbedded with an occasional lenticular sandstone. The importance of the Bartlesville sand lies in the fact that it is one of the most productive oil and gas reservoirs in the Mid-Continent oil and gas field. As shown in Plate XLVII, in the southern part of T. 27 N., R. 10 E., it has an average thickness of about 15 feet, and this figure probably represents a fair average for the remainder of the township. The area in which the Bartlesville sand is virtually proved productive is shown on Plate XLVIII. The fact that this sand is present over most of the part of the township that has been drilled but is productive over only a relatively small area probably means that the sandstone is too tightly cemented to serve as an oil or gas reservoir outside of the area indicated by shading on Plate XLVIII. The term Bartlesville has been applied to any sand found at about the stratigraphic position of this sand, as indicated on Plate XLVII. It is likely that these sands found at different localities in the Osage Reservation are approximately of the same age, but it is unlikely that they represent one continuous sand body.

The "Mississippi lime" is stratigraphically below the Bartlesville sand and is separated from it by about 105 feet of shale. Some of the well logs record a sandstone 10 to 20 feet thick just above the top of the "Mississippi lime," and other logs record a sandstone 20 to 30 feet below the top of the limestone. Both of these sandstones are classed by the drillers as part of the "Mississippi lime." The upper 70 feet of this formation is important commercially because a large number of the producing wells in T. 27 N., R. 10 E., derive their oil and gas from these beds. Well 153, Plate XLVIII, is reported to have been drilled to a depth of 2,245 feet and to have reached the top of the "Mississippi lime" at 1,895 feet. This is within about 15 feet of the position the "Mississippi lime" should occupy below the "Oswego lime" at this locality, if the average interval between the "Oswego lime" and "Mississippi lime" for the southern part of the township is applied here. Because of the economic importance of the beds below the top of the "Mississippi lime" the portion of the driller's record describing these beds is given below.

Log of lower part of well 153, in the NW. ¼ sec. 25, T. 27 N., R. 10 E.

	Depth.		Depth.
	Feet.		*Feet.*
Sandy lime; top of "Mississippi lime"	1,895–1,918	Light slate	2,170–2,200
White sand; smell of oil	1,918–1,927	White sand, show of gas (about 10,000 feet)	2,200–2,210
Black lime	1,927–1,985	Hard lime, light	2,210–2,240
Lime	1,985–2,060	Sand; little more gas, 100 barrels of salt water in 24 hours	2,240–2,245
White lime	2,060–2,120		
Black brick	2,120–2,170		

In brief, the upper 275 feet of the "Mississippi lime," which is made up principally of limestone, overlies a series of sandstones, shales, and limestones that aggregate at least 85 feet in thickness, and these sandstones are known to contain some gas. The "Mississippi lime" is tentatively correlated with the Boone chert, which crops out in the northeast corner of Oklahoma, but it is believed that the possibility of correlating the "Mississippi lime" with one of the limestones above the Boone chert should at least be considered. The Morrow and Pitkin limestones, which overlie the Boone chert, also crop out in eastern Oklahoma. The Pitkin is of Mississippian age, but the Morrow is Pennsylvanian. It is not impossible that the "Mississippi lime" recorded in some of the well logs is the stratigraphic equivalent of the Morrow and Pitkin, but as the matter stands now it is entirely an open question. The question is one of material economic importance, because of the possibility of finding deeper sands than those now known to produce oil and gas in this township. In this connection it is appropriate to consider means of distinguishing between the Boone chert and the younger Mississippian limestone. The Boone chert is more siliceous than the overlying limestones and it should cut the bit of the drill faster than a limestone that contains a smaller amount of silica. Whenever practicable fragments of drill cuttings or lumps of the material obtained after shooting the producing bed in the limestone should be examined for fossils and the amount of silica they contain should be noted.

CONVERGENCES OF THE SUBSURFACE BEDS.

By averaging the measurements between certain key beds in the wells listed in the table of well data (pp. 325–327), it is possible to arrive at certain conclusions relative to the intervals in different parts of the township between individual subsurface beds and also between these beds and those at the surface. In general the beds converge toward the north; or, in other words, the interval between two particular beds in the southern part of the township is greater than the measured distance between these same two beds in the northern part. The economic application of this difference is evident, for wells drilled in the southern part of the township will have to go deeper than wells drilled in the northern part to reach the same sand, if the wells are started on the same surface bed. The stratigraphic interval between the surface beds and the top of the "Oswego lime" is greater by 30 feet in the southern part of sec. 36 than it is in the center of sec. 13, and greater by 100 feet in the southern part of sec. 36 than it is in the northern part of sec. 1. The interval between the top of the "Oswego lime" and the top of the "Mississippi lime" in the southeast corner of sec. 36 is greater by about 30 feet than the interval between these same beds in the center of sec. 13. It appears that the direction and amount of the convergence between the surface beds and the "Oswego lime" are approximately the same as between the "Oswego lime" and the "Mississippi lime." A few examples will give an idea of the depth necessary to drill in order to reach the "Mississippi lime" at a number of points on the surface of the township. A well drilled in the SE. ¼ sec. 36, starting at the top of the Labadie limestone at the surface, should reach the "Mississippi lime" at a depth of 1,985 feet; a well drilled in the center of sec. 34, at the same surface horizon, should reach the "Mississippi lime" at a depth of 1,955 feet; a well starting on the same surface bed in the center of sec. 13 should reach the lime at a depth of about 1,935 feet; and in sec. 1 the drill, after going through the Labadie limestone, would still have to penetrate about 1,835 feet of strata before reaching the top of the "Mississippi lime."

STRUCTURAL FEATURES.

GENERAL DESCRIPTION.

The structure of T. 27 N., R. 10 E., is graphically shown on Plate XLVI by means of structure contours that have an interval of 10 feet. These contours are based entirely on the structure of the surface rocks and are so drawn as to show the elevation above sea level, in feet, of a theoretical bed 560 feet below the top of the Plummer limestone member of the Pawhuska limestone. Where the field evidence is sound, the contours are drawn with solid lines, but where the correlations are doubtful or the exposures poor, the contour lines are broken to indicate the lack of conclusive evidence. It will be noted that the highest structure contour shown on Plate XLVI (the 870-foot contour) is in the extreme southeast corner of the township, and the lowest structure contour (the 610-foot contour) is confined to the western edge of the township. The general dip across the township, then, is in a westerly direction and is between 30 and 40 feet to the mile, agreeing very well in direction and amount with the general or normal dip of the Pennsylvanian rocks in northern Oklahoma.

The approximate position of the anticlinal axes in T. 27 N., R. 10 E., is graphically shown in figure 45. As it is generally conceded that such structural features as domes, anticlines, and terraces offer greater promise for oil and gas accumulation than unfolded areas, it is appropriate here to describe the salient points of these structural features.

ANTICLINES AND DOMES.

Dry Hollow dome.—The approximate position of the axis of the Dry Hollow dome is shown in figure 45 to lie in the southern part of sec. 35, and although the trend is not very pronounced, it seems to have a general direction of northwest and southeast. Only the northern flank of this dome is shown on Plate XLVI, but comparison with the structure map of T. 26 N., R. 10 E.,[1] shows that this dome has a closure of about 20 feet. The Dry Hollow dome is characterized by a relatively steep dip on its western flank and moderate but well-developed dips on the other flanks.

Whitetail anticline.—The axis of the Whitetail anticline, which has a northeasterly trend, cuts diagonally across the SE. ¼ sec. 31. It is continuous with the Albert anticline, described by F. R. Clark,[2] and is a part of the same fold. The crest of the anticline is cut off sharply to the east by a fault with a northwesterly trend, which has caused a vertical displacement of more than 30 feet. The rocks immediately east of the fault and in line with the anticlinal axis to

[1] Clark, F. R., U. S. Geol. Survey Bull. 686-I, pl. 14, 1918. [2] Idem, p. 100.

the west have been depressed into a syncline, which is also cut off sharply by the fault. The northern flank of the Whitetail anticline is also cut by a small fault that is approximately parallel to the one described above. The western part of the crest of the anticline grades into a flat terrace-like feature, with a rather irregular outline. A nose extends southwestward into sec. 1, T. 24 N., R. 9 W.

Bellieu dome.—The axis of the Bellieu dome has a northwesterly trend and intersects the northwest corner of sec. 26. (See fig. 45.)

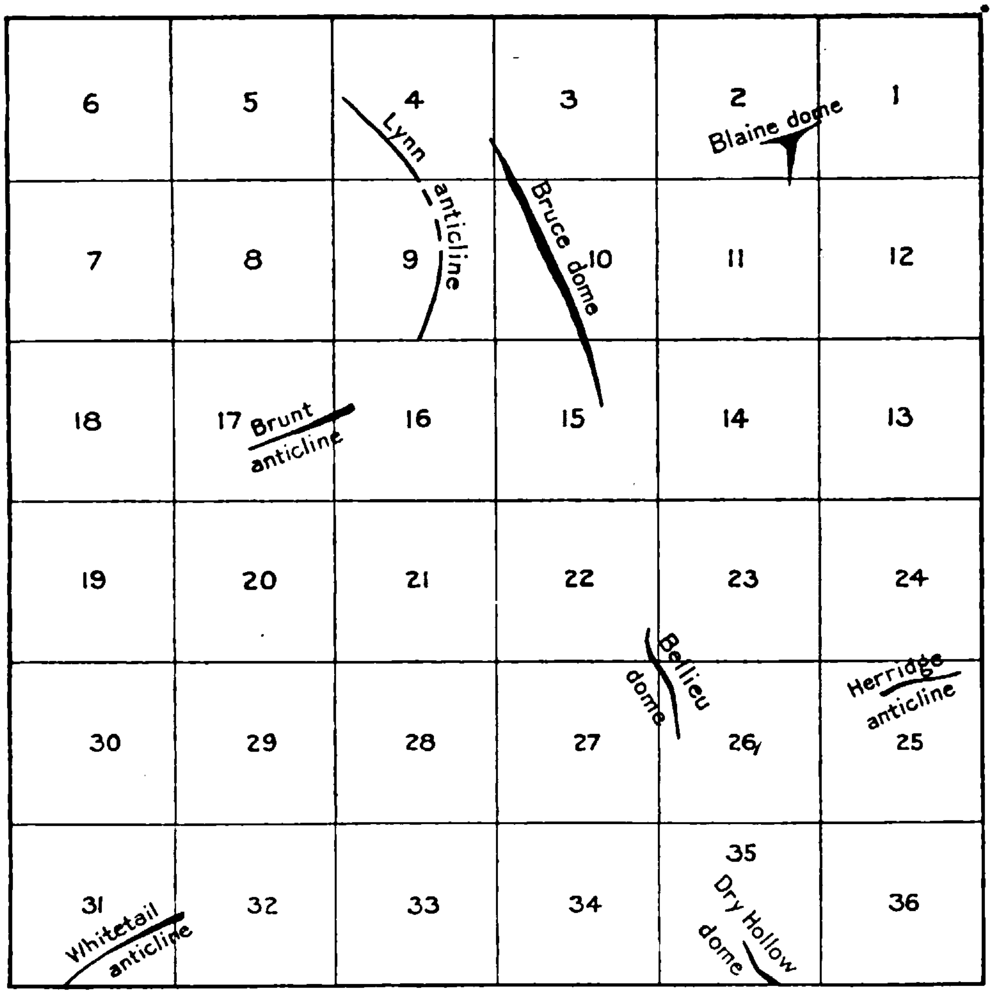


FIGURE 45.—Diagram showing approximate positions of anticlinal axes in T. 27 N., R. 10 E.

This dome has a closure of about 20 feet and is separated from the Dry Hollow dome by a shallow structural saddle. The steepest dips on this dome are on its northern flank.

Herridge anticline.—The axis of the Herridge anticline is shown in figure 45 to have a general northeasterly trend and to cut across the N. ½ sec. 25. East of sec. 25 the Herridge anticline merges into a structural terrace. In secs. 24 and 25 it has well-developed north, south, and west dips.

Blaine dome.—The Blaine dome covers a large part of sec. 2 and fractions of secs. 1, 12, and 11. As shown on Plate XLVI, it has a closure of about 30 feet.

Bruce dome.—The Bruce dome is a relatively large, elongated dome with a closure of about 60 feet. As shown in figure 45, its axis has a northwesterly trend and cuts across the extreme southwest corner of sec. 3, intersects sec. 10 diagonally, and extends into the north-central part of sec. 15. As shown on Plate XLVI, the Bruce dome is faulted on its western flank and appears to be crowded into the Lynn and Brunt anticlines described below.

Lynn anticline.—As shown in figure 45, the axis of the Lynn anticline is curved and intersects portions of secs. 4 and 9. The anticlinal structure is shown by well-developed dips to the north, west, south, and southeast, but it is complicated by a series of faults, which have a general northwesterly trend. The fault that forms the eastern boundary of this anticline is one of the largest faults mapped in the Osage Reservation. It has been mapped for a distance of about 2 miles and has a maximum vertical displacement of a little over 60 feet. Just west of the center of this fault the rocks show a well-developed anticlinal structure, as described above, whereas to the east of the fault, east of the crest or highest part of the Lynn anticline, the rocks are bowed downward into a shallow syncline. The large fault is paralleled on the west by a number of faults of relatively small vertical displacement. All the faults are normal, and all of them have their downthrow side toward the east.

Brunt anticline.—The Brunt anticline may be considered as an extension of the southwestern limb of the Lynn anticline. Its axis has a northeasterly trend and cuts across the west-central part of sec. 16 and the east-central part of sec. 17. The anticline is bounded on the east by a normal fault whose downthrow is on the east side and which is approximately parallel to the faults associated with the Lynn anticline.

TRENDS OF FOLDS AND FAULTS.

Some of the anticlinal axes represented in figure 45 show certain general alinements. Probably the best example of this is the northwest-southeast line made by the axes of the Bruce dome, the Bellieu dome, and the Dry Hollow dome. Inspection of Plate XLVI shows that there is an almost continuous synclinal depression which extends from a point near the center of sec. 12 through the southwest corner of sec. 14 and the southwest corner of sec. 21 and across the NW. ¼ sec. 31. It thus seems that there are at least two general lines of folding in this township that are nearly at right angles to each other. The Bruce dome, the Lynn anticline, and the Brunt anticline appear to form a part of a general upfolded area that has been more or less broken up by parallel normal faults. It is noteworthy that all of the faults are normal; that they are more or less parallel, and that the downthrow in each is on the east side of the fault plane. As described above, a few of the faults in this township are bordered on the east by a syncline and on the west by an anticline. It seems that the strata have undergone tangential stresses and that relief from these stresses has been accomplished by a flexing of the rocks in some places and by rupture or faulting in others. The location of the folds and faults has probably been determined, at least in part, by the rigidity and weight of the rock segments operating with the tangential stresses.

SAND CONDITIONS.

In an area that has produced oil and gas it is important to consider the productive beds and to outline as far as possible the areas in which they are productive. An attempt has been made to indicate these areas for the east side of the township in Plate XLVIII, which shows, in addition to the development work in the township (the oil and gas wells, the dry holes, and the abandoned wells), the probable area in which the Bartlesville sand is essentially proved to be productive, and an approximate outline of the known productive area of the principal stray sand. The wells are numbered to agree with the numbered wells in the table of well data at the end of this report. The oil and gas produced in this township come from five beds, which in their order of depth from the surface are (1) a stray sand about 150 feet above the top of the Little lime, (2) a stray sand between the Little lime and the Big lime, (3) the Bartlesville sand, (4) a stray sand between the Bartlesville sand and the "Mississippi lime," and (5) the sands in and associated with the top of the "Mississippi lime." It is noteworthy that in this township there is no record of oil or gas production of importance from the Big lime or the "Oswego lime" or from the Peru sand, which should be found between these two limes. The principal productive beds of the township are briefly described below.

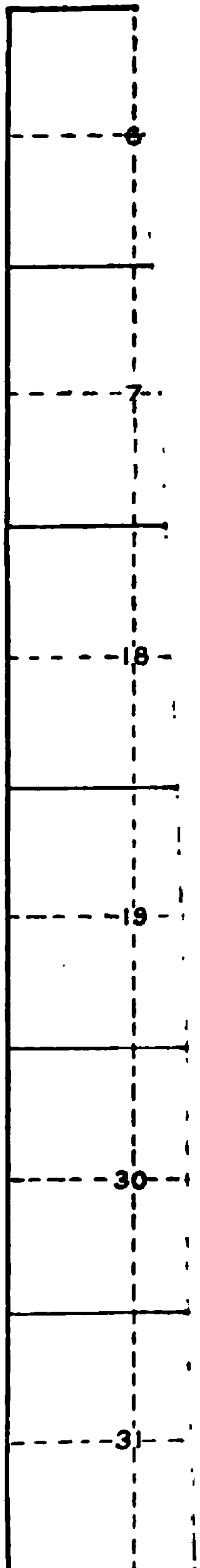
Stray sand above the Little lime.—There is only one well in this township that is reported to have produced oil or gas from a sand above the Little lime. Well 3, in the NW. ¼ sec. 1, is reported to have had an initial production of 2,000,000 cubic feet of gas a day, presumably from a sand between 894 and 961 feet below the surface and about 150 feet above the top of the Little lime. As "offset" wells to well 3 have been drilled to deeper sands without recording production from this stray sand, the conclusion seems justified that the productive area of this sand is very small and it is unlikely that the sand will supply any large amount of oil or gas in this township.

Stray sand between the Little lime and the Big lime.—The approximate area within which the sand between the Little lime and the Big lime is essentially proved to be productive in the eastern part of the township is graphically shown in Plate XLVIII. The probable productive area of the sand includes appreciable parts of secs. 11, 12, 13, 14, 15, and 23. It should be noted that the boundary of this productive area is not indicated by a clean-cut line, for it is impossible to outline precisely the productive area of any sand ahead of the drill. This estimate of prospective oil and gas territory may be regarded as a conservative one. The maximum thickness recorded for this stray sand is 96 feet, and an average thickness over the productive area is about 40 feet. The average initial production of the wells from this sand is about 40 barrels of oil a day. From the available records it appears to be a common practice to shoot this sand with rather large shots (200 to 300 quarts of nitroglycerin are not uncommon), which would seem to indicate that the sand is rather tightly cemented and that thorough breaking up is necessary to increase the production of oil and gas.

Stray sand between the "Oswego lime" and the Bartlesville sand.—A sand about 70 feet below the base of the "Oswego lime" is reported to have produced initially about 2,750,000 cubic feet of gas daily from well 177, in the NE. ¼ sec. 34, and what is probably the same sand is reported to have produced gas in well 206, in the SE. ¼ sec. 35. The probable productive area of this sand may be indicated on the map as that area embraced by a line connecting wells 177, 205, 206, and 202. The maximum thickness recorded for this sand is 61 feet.

Bartlesville sand.—The area in which the Bartlesville sand is practically proved to be productive in this township is graphically shown in Plate XLVIII. It covers substantial parts of secs. 34, 35, and 36. This does not mean, however, that the sand is not present outside of the area indicated by shading in Plate XLVIII. On the contrary, the records of a large number of the wells drilled in many parts of the township outside of that area have proved that the Bartlesville sand is present over most of the township where the drill has gone deep enough to test that sand. It is likely, however, that over much of the region outside of the area indicated by shading the sand is too tightly cemented to serve as a good oil and gas reservoir. In this connection it is noteworthy that a few wells outside of the probable productive area are reported to have produced oil from the Bartlesville sand, although "offset" wells were drilled through the sand without getting commercial quantities of oil or gas. Concrete examples of this may be found in well 116, in the SE. ¼ sec. 23; well 102, in the NE. ¼ sec. 22; and well 5, in the SW. ¼ sec. 1. In a few of the wells the Bartlesville sand was recorded

U. S. GE



DIAGRAM

as being as thick as 30 feet; in others the sand appears to be absent; and an average thickness of the sand as recorded in the available logs is about 16 feet. The initial daily production of a few of the wells in the Bartlesville sand exceeded 100 barrels of oil, but the average initial production from this sand amounted to about 55 barrels.

"Mississippi lime."—The oil and gas obtained from the "Mississippi lime" comes from the upper 50 feet of the formation. In some places the oil comes from a sand immediately above the lime; in others it is reported from the lime itself; and in still others it is from a sandstone 20 to 30 feet below the top of the lime. The area in which the "Mississippi lime" is productive does not seem to be determined by the condition of the sand or rock that acts as reservoir but is apparently defined in large part by the structural features of the township, which are discussed in a later part of this report. The average initial production of the wells in this township that produce oil from the "Mississippi lime" is between 20 and 25 barrels of oil a day. Wells that produce more than 50 barrels of oil a day are exceptional.

Possible productive sands below the "Mississippi lime."—Oil in commercial quantities is reported to have been found in sands more than 200 feet below the top of the "Mississippi lime" in several localities in Oklahoma. According to R. H. Wood,[1]

The oil limitations are not reached at the top of the "Mississippi lime" in northeastern Oklahoma, as production has been obtained in a number of localities by drilling into or through that formation some 300 feet. Concrete examples may be found in Barnsdall Oil Co.'s wells 374 and 407, in sec. 8, T. 20 N., R. 12 E. In well 374 the "Mississippi lime" was reached at 1,850 feet and the top of a sand at 2,125 feet, which continued to 2,178 feet. This is 275 feet below the top of the lime. This deep sand produced initially, according to the superintendent, 1,000,000 feet of gas and 312 barrels of oil a day. Farther west, in sec. 14, T. 22 N., R. 8 E., the Red Bank Oil Co. has within the last two weeks completed a "Mississippi lime" well, but no data are available except those appearing in the trade journals. It is reported that the "Mississippi lime" was found at 2,545 feet and some oil at 2,579 feet. A sand was found at 2,850 feet, and drilling continued to 2,886 feet. The well is now said to be producing 30 barrels daily, presumably from the deep sand. In T. 20 N., R. 11 E., the Phoenix Refining Co. has drilled a number of wells near Sand Springs, some 300 feet below the top of the "Mississippi lime," and obtained production there. The first of these wells was reported to produce initially 1,500 barrels daily. This oil is of very high grade. Between Sapulpa and Tulsa and nearly east of Sapulpa some wells have been drilled several hundred feet into the "Mississippi lime" and found to yield high-grade oil. With only meager data in hand it is impossible to determine in every instance whether the "Mississippi lime" is Boone or Morrow and Pitkin.

In sec. 25 of the township under discussion, well 153 is reported to have obtained over 1,000,000 cubic feet of gas a day from a sand more than 300 feet below the top of the "Mississippi lime." In

[1] Informal communication, Jan. 25, 1918.

view of the evidence above set forth, the statement seems justified that no area in T. 27 N., R. 10 E., should be considered completely tested until a depth of 400 feet below the top of the "Mississippi lime" is reached.

AREAS OF FAVORABLE STRUCTURE FOR THE ACCUMULATION OF OIL AND GAS.

GENERAL RELATIONS.

Although not enough work has been done at the date of this writing to permit the formulation of definite conclusions regarding the relation between surface structure and oil and gas production in the Osage Reservation, it is believed that certain generalizations may be made from a study of the structure contour maps of different parts of the reservation on which the producing oil and gas wells are plotted. It is fully demonstrated that areas occupied by anticlines, domes, and terraces are more promising prospective oil and gas territory than areas in which the strata are not so folded, provided, of course, that sand conditions and other factors are equal. It seems to be generally true also that the crests of the anticlines and domes in the Osage Reservation are more likely to be productive of gas than of oil, and that the western flanks, particularly the northwestern portions, of the anticlines and domes are more productive than the eastern flanks, and the productive area extends farther down structurally from the crests of the folds on the west than on the east. These generalizations form the basis for most of the recommendations made below in outlining the areas that seem to be well located structurally, but the known and probable productive areas of the sands associated with the anticlines and domes are also discussed.

Because the generalizations given above can not be laid down as definite rules, and because of the impossibility of forecasting the nature of a sand with certainty ahead of the drill, it is emphasized that the recommendations here made do not constitute a guaranty that oil or gas will be found in the areas outlined. They do represent, however, the best estimates the writers can make, and it is believed that losses by futile drilling will be materially reduced if the areas are tested in accordance with these recommendations.

DRY HOLLOW DOME.

Stray sands above the Bartlesville sand.—The table of well data at the end of this report gives records of three wells that have produced oil and gas from sands above the Bartlesville in the area covered by the Dry Hollow dome. Well 177, in the NE. ¼ sec. 34, is reported to have produced initially about 2,750,000 cubic feet of gas a day from a sand about 70 feet below the base of the "Oswego lime." Well 205, in the SW. ¼ sec. 35, is reported to yield a small quantity of oil from a sand that is estimated to be between 1,420 and 1,430 feet from the surface. Well 206, in the SE. ¼ sec. 35, is reported to have produced gas from a sand between 1,606 and 1,627 feet from the surface, which is about the same stratigraphic position as the sand in well 177, mentioned above. Other records from sec. 35 without exact locations indicate production from a sand between the "Oswego lime" and the Bartlesville sand, probably the equivalent in age to the sand in well 177. The productive area of this sand is probably limited to a narrow strip along the northeastern flank of the anticline, which may be roughly outlined on the map as embracing the area surrounded by a line connecting wells 177, 205, 206, and 202.

Bartlesville sand.—The area in which the Bartlesville sand is probably productive in the Dry Hollow dome is outlined in Plate XLVIII and as shown there covers parts of secs. 34 and 35. The average initial daily production of the wells from the Bartlesville sand in the area so outlined is between 70 and 75 barrels of oil. The average thickness of the sand over the productive area is between 15 and 20 feet.

"*Mississippi lime.*"—As oil or gas in commercial quantities is obtained above the "Mississippi lime" in most of the wells drilled on the Dry Hollow dome, very few of the wells are deep enough to test the "Mississippi lime." Well 201, in the extreme northwest corner of sec. 35, is reported to have had an initial daily production of 6 barrels of oil from the "Mississippi lime." Inasmuch as this bed is widely productive in this and adjacent townships it seems reasonable to assume that there is a very good chance of finding oil and gas in it on the Dry Hollow dome when the wells that now tap the Bartlesville sand are deepened or when new wells are drilled deep enough to test the lime. The area that may be classed as a prospective source of oil or gas from the "Mississippi lime" may be roughly outlined as embracing the territory indicated by shading on Plate XLVIII as favorable area for the Bartlesville sand on the Dry Hollow dome, plus enough territory to the north to include well 201. The area so outlined includes a good part of the SE. ¼ sec. 35, all of the SW. ¼ sec. 35, the major part of the NW. ¼ sec. 35, approximately the southeast half of the NE. ¼ sec. 34, all of the SE. ¼ sec. 34, and a strip along the east side of the SW. ¼ sec. 34. As stated in the discussion of the sand conditions, the average initial production of the wells in this township from the "Mississippi lime" is between 20 and 25 barrels of oil a day, and until the area is proved by the drill this figure may be taken as the probable average initial production of the wells that may in the future produce from the "Mississippi lime."

WHITETAIL ANTICLINE.

The Whitetail anticline has not been tested by the drill for oil or gas, and consequently it is difficult to say much about the sand conditions on it. Productive sands above the Bartlesville may be encountered in this anticline, but there is no possible way of predicting this in advance of the drill. The Bartlesville sand is likely to be productive in the southern tier of sections in T. 27 N., R. 11 E., and the eastern part of T. 27 N., R. 10 E. The "Mississippi lime" should probably be classed as the most promising source of oil and gas in the Whitetail anticline, although the average initial production from the "Mississippi lime" in wells in this township is only about 20 or 25 barrels of oil a day. The upper part of the lime is known to yield oil or gas in most of the wells in this township that are favorably located in regard to structure.

The part of the Whitetail anticline which should receive a higher rating as prospective oil and gas territory than the adjacent area may be outlined (see Pl. XLVI) as that part of sec. 32 which lies southwest of the fault and within the 650-foot contour in the SW. ¼ and that part of sec. 31 which lies southwest of the fault that cuts the eastern boundary of the section and which is partly surrounded by the 650-foot contour.

BELLIEU DOME.

Stray sand.—As shown in Plate XLVIII the essentially proved productive area of the stray sand which is found between the Little lime and the Big lime covers a part of the northeastern flank of the Bellieu dome. It is likely that the productive area of this sand will be found to extend to the north beyond the area covered by the Bellieu dome, or beyond the central and northern parts of sec. 23. Well 106 is credited with an initial production of 20 barrels of oil a day after being shot, and well 107 with an initial production of 30 barrels. Both of these wells found the sand at a depth of about 1,295 feet.

Bartlesville sand.—Well 102 is reported to have had an initial production from the Bartlesville sand of 40 barrels of oil a day, although the "offset" wells around it are not credited with producing from this sand. Presumably the Bartlesville sand over most of the area covered by the Bellieu dome is too tightly cemented to serve as an oil or gas reservoir, but in an occasional well the sand is found to be open and productive. The Bartlesville sand can not, however, be considered an important source of oil or gas here, and no attempt is made to outline its probable productive area on the Bellieu dome, but if a good show of oil is found in this sand in any of the wells drilled here the sand should be shot in order to test it thoroughly for oil or gas.

"*Mississippi lime.*"—The "Mississippi lime" is the most important oil and gas reservoir in the area covered by the Bellieu dome. The crest of the dome has been proved to be gas territory by wells credited with initial yields between 1,000,000 and 4,500,000 cubic feet of gas a day. This gas territory may be described as including the area encircled by lines connecting wells 103, 104, 172, 169, 168, 159, 158, and 103. It is not unlikely that oil will be found on the western flank of the Bellieu dome. The 740-foot contour may be taken as the northern and western limit of the probable oil territory in sec. 22, and a line connecting the point where this contour crosses the southern boundary of sec. 22 with well 201 may be considered tentatively as the southwestern boundary of the probable oil territory on the Bellieu dome.

HERRIDGE ANTICLINE.

Stray sands above the Bartlesville sand.—A number of wells have been drilled on the Herridge anticline, but no oil or gas of commercial importance from sands above the Bartlesville is recorded in the available well logs. In view of this fact, there seems to be little promise of obtaining oil or gas in commercial quantities from these sands.

Bartlesville sand.—Of the available well logs there is one record, that of well 116, that reports oil from the Bartlesville sand in the area covered by the Herridge anticline. In this log the sand is reported to be 12 feet thick and it is credited with an initial production of 10 barrels of oil a day. This well is surrounded by wells that produce oil from the "Mississippi lime" and that consequently must have been drilled through the Bartlesville sand without getting enough oil or gas to make paying wells. The conclusion seems warranted that the Bartlesville sand in the area of the Herridge anticline is irregularly cemented, and although oil or gas may be obtained from it in occasional wells it can not be counted upon as an important reservoir.

"*Mississippi lime.*"—East of the Herridge anticline the strata flatten out into what is called in T. 27 N., R. 11 E., the Levelette terrace. The Levelette terrace merges into the Bacon Rind anticline toward the north so that these three structural features—the Herridge anticline, in T. 27 N., R. 10 E., and the Levelette terrace and Bacon Rind anticline in T. 27 N., R. 11 E.—influence the accumulation of oil and gas in the area discussed below.

A glance at Plate XLVI shows that over 50 wells have been drilled on or near the Herridge anticline. Almost all these wells produce oil from the "Mississippi lime," and their average initial production was about 20 barrels of oil a day. The probable productive area associated with these structural features may be outlined as embracing the territory in sec. 13 southeast of the 790-foot structure contour (see Pl. XLVI), all of sec. 24 except that part northwest of the 790-foot contour, that part of the SE. ¼ sec. 23 that lies southeast of the 780-foot contour, approximately the E. ½ NE. ¼ sec. 26, a small part of the NE. ¼ SE. ¼ sec. 26, and the N. ½ sec. 25.

BLAINE DOME.

Stray sand above the Bartlesville sand.—Well 3, in the NW. ¼ sec. 1, is reported to have had an initial daily production of 2,000,000 cubic feet of gas, presumably from a sand between 894 and 961 feet below the surface. The top of this sand is about 215 feet above the top of the Little lime, and according to the well data available this is the only well in the township that produces oil or gas from a sand at this horizon. As the logs of "offset" wells to well 3 drilled through this sand did not report production from it, the conclusion seems warranted that the productive area of the sand is very small, and no attempt is made to predict its extension beyond the area drained by well 3.

Bartlesville sand.—Well 5, in the extreme southwest corner of sec. 1, is reported as a gas well from the Bartlesville sand. As described earlier in this report, the Bartlesville sand has not been found to be productive outside of the area indicated by shading on Plate XLVIII, except in a few scattered wells, most of which are partly surrounded by deeper wells that are not credited with production from that sand. It seems rather unlikely that the Bartlesville sand will supply any great amount of oil or gas in the area covered by the Blaine dome, but if a good show of oil is encountered in this sand the sand should be shot before it is cased off.

"*Mississippi lime.*"—Some of the walls on the Blaine dome have been drilled deep enough to test the "Mississippi lime," and those which were located near the crest of the dome are reported as gas wells. The southeastern and southern boundaries of the probable productive area on the southern and southeastern flanks of the Blaine dome may coincide with the 780-foot structure contour (Pl. XLVI). The productive area on the northwestern flank may be limited by the 760-foot contour. The crest of the dome should be classed as gas territory, and the area well down on the northwestern flank of the dome, within the area outlined as probable productive territory, has a chance for oil.

BRUCE DOME, LYNN ANTICLINE, AND BRUNT ANTICLINE.

The Brunt and Lynn anticlines are very closely associated with the Bruce dome, and it is difficult to separate the discussions of the probable productive area of these structural features. Therefore they are treated as a structural group and their probable productive area is outlined as a single unit.

Stray sands above the Bartlesville sand.—As indicated in Plate XLVIII, the stray sand that is found stratigraphically between the Little and Big limes has been proved productive in the E. ½ sec. 15 and the greater part of sec. 14. This area embraces a part of the southeastern flank of the Bruce dome. The maximum initial daily production from the wells on this flank is recorded as about 80 barrels of oil from well 63, in which the sand is at 1,242 to 1,272 feet below the surface.

A gas well has been reported, through the press, in the SW. ¼ SE. ¼ sec. 10, which produces from the "Mississippi lime," the sand between the Little and Big limes presumably being dry. It has also been reported through the press that a hole has been drilled in the NE. ¼ sec. 10 to a depth of 1,300 feet without obtaining oil or gas in commercial quantities from the sand between the Little and Big limes. It seems possible, therefore, that the western limit of the productive area of this stray sand lies to the east of these two wells.

Two gas wells in the NW. ¼ sec. 4 have been reported, through the trade journals and the press. These two wells are said to have had initial daily yields of 4,000,000 and 5,000,000 cubic feet of gas, respectively, from a sand between 1,200 and 1,300 feet below the surface. Although logs of these wells are not at hand at the time of writing, it is not unlikely that this sand is equivalent in age to the stray sand. The two wells in sec. 10 may, however, be interpreted as indicating a separation of the gas territory in the NW. ¼ sec. 4 from the proved area in sec. 14 and adjacent territory.

Bartlesville sand.—Very little can be said about the Bartlesville sand in the area covered by the Bruce dome and the Lynn and Brunt anticlines. No commercial production of either oil or gas has been recorded from the sand in this area, but the area is large and has been tested at only three localities—well 72, in the northwest corner of sec. 14; well 97, near the center of sec. 17; and a well recently drilled in the NW. ¼ sec. 9, the exact location of which is not known to the writers. None of these wells produced either oil or gas in commercial quantities from the Bartlesville sand. The essentially proved area of the Bartlesville sand, as outlined on Plate XLVIII, lies several miles south of the area under discussion. All things considered, the outlook for important production from this sand in this area is not very promising, but if a good show of oil is found the sand should be shot before drilling deeper.

"*Mississippi lime.*"—Only a few wells have been drilled deep enough to test the "Mississippi lime" in the area covered by the Bruce dome and the Lynn and Brunt anticlines. Well 72, in the extreme northwest corner of sec. 14, is reported to have reached the "Mississippi lime" at a depth of 1,932 feet and there obtained an initial production of 20 barrels of oil a day. A well in the SW. ¼

SE. ¼ sec. 10 has been reported through the press to have had an initial production of 1,500,000 cubic feet of gas a day from a sand between 1,965 and 1,983 feet from the surface, which is about the right depth for the "Mississippi lime" at this locality. The well reported to have been drilled in the NE. ¼ sec. 10 was not deep enough to test the "Mississippi lime." A well is reported, through the press, to have been drilled in the NW. ¼ sec. 9, near the center of the north line of the quarter section. The sand is reported to have been found between 1,991 and 2,018 feet below the surface and this is probably the "Mississippi lime." The initial production is said to have been about 7 barrels of oil a day. At locality 97 a dry hole has been drilled to a reported depth of 2,070 feet, which was deep enough to test the "Mississippi lime."

The portion of the area covered by the Bruce dome and the Lynn and Brunt anticlines which is believed to have a relatively higher rating as prospective oil or gas territory, if the top of the "Mississippi lime" is regarded as the pay sand, than the adjacent country may be outlined in a general way as follows: The eastern and northeastern boundary of this probable productive area is tentatively limited by the 780-foot contour on the eastern and northeastern flanks of the Bruce dome. (See Pl. XLVI.) The area may extend down from the crest of the Bruce dome to a line made by the 770-foot contour on the southern flank of the dome. The southwestern flank of the Bruce dome and the southern flank of the Lynn anticline may be considered as probable productive territory as far down from their crests as the 760-foot contour. The probable productive area of the Brunt anticline may be roughly outlined as embracing the territory that is partly encircled by the 760-foot contour, which includes a substantial part of the E. ½ sec. 17 and extends into sec. 16 and there merges into the territory described above as the probable productive part of the south flank of the Lynn anticline. The western flank of the Lynn anticline may be considered as probably productive as far down from its crest as the 760-foot contour, and the north flank of both this anticline and the Bruce dome may be found to be productive as far down from their crests as the 770-foot contour. As outlined above, the area that will probably be found to carry oil or gas in the "Mississippi lime" in the area covered by the Bruce dome, the Lynn anticline, and the Brunt anticline embraces a substantial part of the SW. ¼ sec. 3; all of sec. 10 except a portion of the NE. ¼; a relatively small fraction of the SW. ¼ sec. 11; a small fraction of the NW. ¼ sec. 14; the N. ½ and a part of the S. ½ sec. 15; the NE. ¼ and a substantial part of the W. ½ sec. 16; the greater part of the E. ½ sec. 17; all of sec. 9 except a strip about a quarter of a mile wide (east to west) and a mile long (north to south) in the western part of the section; all of sec. 4 except very small fractions of the southwest and northwest corners and a relatively larger fraction in the northeast corner; and a relatively small area in the eastern part of sec. 5.

The crests of the Bruce dome, the Lynn anticline, and the Brunt anticline are more likely to yield gas than oil, and the western flanks of these structural features should in part, at least, produce some oil. It is believed that the faults shown on Plate XLVI that cut the Lynn and Brunt anticlines do not materially lower the rating of the prospective oil and gas value of the area covered by these folds. There is no surface evidence of oil or gas seepages, and if there has been no leakage of oil or gas along the fault planes it is likely that the faults have served to aid in trapping the oil and gas.

OTHER PROBABLE PRODUCTIVE AREAS.

On Plate XLVIII a part of the SE. ¼ sec. 36 is indicated as productive territory of the Bartlesville sand. The same area may be also classed as probable productive territory of the "Mississippi lime," although the wells within the area indicated by shading have not been drilled deep enough to test the upper part of the "Mississippi lime." This area occupies a part of the western flank of the Sand Creek anticline, which lies in sec. 31, T. 27 N., R. 11 E.; sec. 6, T. 26 N., R. 11 E.; and secs. 1, 12, and 11, T. 26 N., R. 10 E. The initial production of the oil wells in the SE. ¼ sec. 36 of the township under discussion ranges from 2 to 40 barrels of oil a day, from the Bartlesville sand. The Bartlesville sand is 18 feet thick in the SE. ¼ sec. 36, according to the available well records. The sands above the Bartlesville have been adequately tested in this area, but no commercial quantities of oil or gas have been found in them.

As indicated in Plate XLVIII, the sand between the Little and Big limes, which is usually found between 1,200 and 1,300 feet below the surface, is expected to be productive over a large portion of the central and southeastern parts of sec. 11, a substantial portion of the southwestern part of sec. 12, a relatively small fraction of the NW. ¼ sec. 13, practically all of sec. 14, a part of the E. ½ sec. 15, and a large portion of the central and northern parts of sec. 23. It should be noted that this area is not located favorably in regard to geologic structure, but on the contrary it occupies the most pronounced structural depression in the township. The explanation is that the oil and gas production here is controlled not by geologic structure but by the character of the sand body. The average thickness of the sand in the producing wells is about 41 feet, and the maximum thickness recorded is 96 feet, in well 93, in the NE. ¼ sec. 15. The average initial daily production of the oil wells within the area indicated by shading on Plate XLVIII is about 45 barrels. It is believed that the productive area is controlled more by the cementation of the sand than by its thickness. Well 93, in which the maximum thickness is recorded, is credited with an initial production of only 5 barrels of oil a day. It seems to be the practice here to use relatively large shots of nitroglycerin (not uncommonly 200 to 300 quarts) to break up the sand in these wells, and this practice suggests that even where the sand is productive it is more or less tightly cemented and that its yield is increased by thoroughly breaking it up.

QUALITY OF THE OIL.

Discussion of analyses of the oil in T. 27 N., R. 10 E., is reserved for the final report on the Pawhuska quadrangle. For the benefit of the reader who is entirely unfamiliar with this field it may be stated that the oil is relatively rich in the lighter hydrocarbons and is classed in price with the oil found in the Bartlesville and Cushing fields. An average specific gravity of the oil measured by the Baumé scale at 60° F. approximates 34.

GENERAL RECOMMENDATIONS.

It is believed that the importance of testing the sands below the "Mississippi lime" is worthy of a second emphasis in this report. The test should first be made on the top of some well-developed anticline or dome, such as the Bruce dome, and if unsuccessful either the Dry Hollow or the Bellieu dome should be tested. Such test wells should be drilled to a depth of 400 feet below the top of the "Mississippi lime."

One of the features shown on Plate XLVI that immediately attracts the eye of the geologist is the large number of oil wells in the most pronounced structural depression in the township, in sec. 14. As explained in another part of this report the production in that area is controlled by the condition of the sand. Because it is impossible to tell in advance of drilling the condition of the sands below the surface, no part of this township is positively condemned for oil or gas. If the sand conditions are uniform the oil in a sand body will be trapped in those places where the geologic structure is favorable, and therefore, if the areas that are located favorably in regard to structure are first tested the risk of failure is greatly lowered. To reduce the risk of failure and to direct the most efficient testing of this township is the prime object of this report.

WELL DATA.

Data on wells in T. 27 N., R. 10 E.

Well No.	Section.	Quarter.	Depth to top of Big lime.	Depth to top of "Oswego lime."	Bartlesville sand.		Depth to top of "Mississippi lime."	Total depth.	Depth of pay sand.	Thickness of pay sand.	Type of well.	Initial daily production.
					Depth to top.	Thickness.						
			Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		
2	1	NW. ¼	1,300	1,480	1,779	10	1,926	1,954			Dry	
3	1	NW. ¼	1,270					1,295	894-961 (stray)	67	Gas	2,00,00 cubic feet.
4	1	NW. ¼	1,280	1,445			1,804	1,886	"Mississippi"	22	do	1,510,860 cubic feet.
5	1	SW. ¼		1,505	1,821	17		1,966	Bartlesville	17	do	
6	2	SE. ¼			1,838	11	1,967	2,011			Dry	
13	11	SW. ¼						1,286	1,240-1,276 (stray)	33	Oil	15 barrels.
18	12	NW. ¼						1,269	1,234-1,263 (stray)	29	Gas	450,000 cubic feet.
20	13	NE. ¼	1,315	1,420			1,900	1,925	"Mississippi"	15	Oil	25 barrels.
21	13	SE. ¼	1,335	1,485	1,807	22	1,935	1,969	do	34	do	40 barrels.
22	13	SE. ¼					1,899	1,921	do	22	do	
23	13	SE. ¼					1,898	1,928	do	30	do	
24	13	SE. ¼	1,278	1,430	1,725	20	1,854	1,870	do	16	Gas	5,000,000 cubic feet.
26	13	SW. ¼		1,425			1,865	1,901			Dry	
35	14	NE. ¼						1,270	1,245-1,270 (stray)	25	Oil	50 barrels.
36	14	NE. ¼						1,254	1,220-1,250 (stray)	30	do	35 barrels.
37	14	NE. ¼						1,251	1,208-1,238 (stray)	30	do	50 barrels.
38	14	NE. ¼						1,298	1,258-1,288 (stray)	30	do	35 barrels.
39	14	NE. ¼						1,298	1,260-1,290 (stray)	30	do	Do.
40	14	NE. ¼						1,251	1,214-1,238 (stray)	24	do	60 barrels.
41	14	NE. ¼						1,238	1,212-1,230 (stray)	18	do	40 barrels.
42	14	NE. ¼						1,250	1,214-1,244 (stray)	30	do	
44	14	NE. ¼						1,264	1,225-1,264 (stray)	39	do	20 barrels.
45	14	NE. ¼						1,296	1,232-1,296 (stray)	34	do	85 barrels.
46	14	NE. ¼						1,283	1,243-1,283 (stray)	40	do	15 barrels.
47	14	NE. ¼						1,297	1,246-1,297 (stray)	51	do	110 barrels.
49	14	NE. ¼						1,306	1,272-1,304 (stray)	32	do	30 barrels.
50	14	NE. ¼						1,340	1,259-1,330 (stray)	71	do	85 barrels.
52	14	NE. ¼						1,272	1,210-1,256 (stray)	46	do	60 barrels.
53	14	NE. ¼						1,266	1,223-1,260 (stray)	27	do	30 barrels.
54	14	NE. ¼						1,288	1,246-1,280 (stray)	34	do	60 barrels.
55	14	NW. ¼						1,283	1,247-1,280 (stray)	33	do	20 barrels.
56	14	NW. ¼						1,284	1,249-1,284 (stray)	35	do	40 barrels.
57	14	NW. ¼						1,318	1,261-1,318 (stray)	57	do	Do.
58	14	NW. ¼						1,283	1,231-1,283 (stray)	52	do	60 barrels.
59	14	NW. ¼						1,341	1,307-1,334 (stray)	27	do	15 barrels.
60	14	NW. ¼						1,359	1,274-1,318 (stray)	44	do	Do.
63	14	NW. ¼						1,274	1,242-1,272 (stray)	30	do	80 barrels.
64	14	NW. ¼						1,281	1,247-1,279 (stray)	32	do	15 barrels.
65	14	NW. ¼						1,287	1,254-1,287 (stray)	33	do	35 barrels.
66	14	NW. ¼						1,277	1,241-1,273 (stray)	32	do	65 barrels.

Data on wells in T. 27 N., R. 10 E.—Continued.

Well No.	Section No.	Quarter.	Depth to top of Big lime.	Depth to top of "Oswego lime."	Bartlesville sand.		Depth to top of "Mississippi lime."	Total depth.	Depth of pay sand.	Thickness of pay sand.	Type of well.	Initial daily production.
					Depth to top.	Thickness.						
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*		
67	14	NW. ¼						1,324	1,241-1,307 (stray)	66	Oil	60 barrels.
69	14	NW. ¼						1,297	1,246-1,287 (stray)	41	do	40 barrels.
70	14	NW. ¼						1,281	1,244-1,276 (stray)	32	do	202 barrels. (?)
71	14	NW. ¼						1,297	1,245-1,291 (stray)	46	do	25 barrels.
72	14	NW. ¼						1,971	Mississippi, 1955	19	do	20 barrels.
73	14	NW. ¼						1,304	1,255-1,294 (stray)	39	do	10 barrels.
74	14	NW. ¼						1,315	1,250-1,304 (stray)	54	do	65 barrels.
75	14	NW. ¼						1,294	1,254-1,294 (stray)	40	do	40 barrels.
76	14	NW. ¼						1,329	1,277-1,324 (stray)	47	do	60 barrels.
77	14	SW. ¼						1,375	1,321-1,371 (stray)	50	do	65 barrels.
80	14	SW. ¼						1,309	1,281-1,307 (stray)	26	do	60 barrels.
81	14	SE. ¼						1,349	1,283-1,341 (stray)	58	do	30 barrels.
82	14	SE. ¼						1,372	1,295-1,372 (stray)	77	do	35 barrels.
85	14	SW. ¼						1,369			do	10 barrels.
86	14	SW. ¼						1,379	1,325-1,379 (stray)	54	do	35 barrels.
87	14	SW. ¼	1,430	1,585	1,855	45	2,005	2,125			Dry	
88	15	SE. ¼						1,382	1,324-1,382 (stray)	58	Oil	10 barrels.
89	15	SE. ¼						1,378	1,322-1,368 (stray)	46	do	15 barrels.
90	15	NE. ¼						1,355	1,321-1,340 (stray)	19	do	25 barrels
91	14	NE. ¼						1,353	1,282-1,348 (stray)	66	do	50 barrels.
92	15	NE. ¼						1,329	1,269-1,323 (stray)	54	do	25 barrels.
93	15	NE. ¼						1,361	1,265-1,361 (stray)	96	do	5 barrels.
97	17	NW. ¼						2,070			Dry	
100	22	NE. ¼	1,465	1,611	1,925	10	2,037	2,078			do	
101	22	NE. ¼	1,435	1,592	1,886	15	2,005	2,035			do	
102	22	NE. ¼	1,435	1,589	1,892	16		1,921	Bartlesville		Oil	40 barrels.
103	22	NE. ¼	1,448	1,589	1,900	15	2,016	2,038	2,025-2,038 ("Mississippi")	13	do	35 barrels.
105	22	SE. ¼	1,412	1,562			1,977	2,004	"Mississippi"	27	Gas	4,000,000 cubic feet.
106	23	NW. ¼						1,325	1,294-1,325 (stray)	31	Oil	20 barrels.
107	23	NW. ¼						1,312	1,295-1,310 (stray)	15	do	30 barrels.
108	23	SW. ¼	1,400	1,509			1,975	2,033	"Mississippi"		Gas	
109	23	SW. ¼	1,380	1,531			1,948	1,978	do	30	do	1,000,000 cubic feet.
113	23	SE. ¼	1,325	1,464			1,893	1,938	1,904-1,925 ("Mississippi")	21	Oil	20 barrels.
114	23	SE. ¼	1,345	1,478			1,886	1,934	"Mississippi"		do	5 barrels.
115	23	SE. ¼	1,270	1,330			1,857	1,895	do	38	do	
116	23	SE. ¼	1,267	1,422	1,728	12		1,874	Bartlesville	12	do	
117	23	SE. ¼	1,360	1,510	1,820	20		1,912				
118	26	NE. ¼	1,300	1,450			1,884	1,919	"Mississippi"	35	Oil	
119	24	SW. ¼	1,250	1,395			1,857	1,941	do		do	3 barrels.
121	24	SW. ¼	1,265	1,410			1,863	1,889	1873-1885 ("Mississippi")	12	do	365 barrels (?).
124	24	SW. ¼	1,275	1,435			1,859	1,909	1884-1905 ("Mississippi")	21	do	
125	24	SW. ¼	1,270	1,365			1,855		"Mississippi"		Gas	

126...	24	SW. ¼					1,813	1,853	"Mississippi"	40	Oil	
127...	24	SW. ¼	1,280	1,435			1,848	1,913	do		do	8 barrels.
130...	24	SW. ¼	1,275	1,430			1,864	1,919	1884–1900 ("Mississippi")	16	do	
133...	24	SW. ¼	1,275	1,420			1,845	1,884	1856–1876 ("Mississippi)	20	do	25 barrels.
134...	24	SW. ¼	1,230	1,360			1,871	1,908	1,871–1,880 ("Mississippi)	9	do	
135...	24	SW. ¼					1,828	1,866	"Mississippi"	38	do	
136...	24	SW. ¼	1,235	1,375			1,809	1,854	do	15	do	
137...	24	SW. ¼					1,804	1,854	do	50	do	
138...	24	SW. ¼					1,807	1,857	do	50	do	
139...	24	SE. ¼					1,789	1,839	do	50	do	
140...	24	SE. ¼	1,295	1,450			1,872	1,931	1,910–1,922 ("Mississippi")	12	do	
141...	24	SE. ¼	1,257	1,405			1,798	1,819	"Mississippi"			
142...	24	SE. ¼	1,195	1,341			1,786	1,833	do	14	Oil	Do.
143...	24	SE. ¼					1,808	1,826	do	5	do	
144...	24	SE. ¼	1,100	1,255			1,788	1,831	do	10	do	
146...	24	NW. ¼	1,175	1,400			1,875	1,918	1,875–1,883 ("Mississippi')	8	do	
147...	24	NW. ¼	1,345	1,500			1,907	1,977	"Mississippi"		do	10 barrels.
148...	24	NW. ¼	1,352	1,510			1,943	2,003	do	32	do	50 barrels.
149...	25	NE. ¼							1,779–1,829 (stray)	50	do	
150...	25	NE. ¼	1,250	1,410			1,855	1,896	"Mississippi"	6	do	10 barrels.
151...	25	NE. ¼	1,295	1,455	1,775	15	1,917	1,938	do	12	do	
152...	25	NW. ¼	1,322	1,476			1,908	1,936	do	30	do	
153...	25	NW. ¼	1,303	1,476			1,895	2,245	2,210–2,215 ("Mississippi")	5	Gas	1,500,000 cubic feet.
154...	25	NW. ¼	1,190	1,370			1,881	1,917	"Mississippi")	18	Oil	
155...	25	NW. ¼	1,275	1,430			1,859	1,910	do		do	
156...	25	NW. ¼	1,230	1,415			1,849	1,888	do		do	
157...	25	NW. ¼	1,250	1,400			1,844	1,868	do	14	do	
158...	26	NW. ¼	1,384	1,528			1,956	1,976	do	20	Gas	4,500,000 cubic feet.
159...	26	NW. ¼	1,410	1,550	1,858	10	1,970	1,990	do		do	3,000,000 cubic feet.
160...	26	NW. ¼	1,380	1,520	1,835	5	2,005	2,027			Oil	
177...	34	NE. ¼	1,390	1,510				1,676	1,615–1,676 (stray)	61	Gas	2,750,000 cubic feet.
179...	34	NE. ¼		1,505	1,837	31		1,868	Bartlesville	31	Oil	35 barrels.
183...	34	SE. ¼	1,381	1,528	1,844	13		1,865	do	13	do	135 barrels.
184...	34	SE. ¼	1,372	1,514	1,834	14		1,852	do	14	do	70 barrels.
186...	34	SE. ¼	1,368	1,520	1,835	14		1,859	do	14	do	50 barrels.
187...	34	SE. ¼		1,476	1,790	16		1,812	do	16	do	55 barrels.
188...	34	SE. ¼		1,513	1,819	21		1,861	do	21	do	100 barrels.
189...	34	SE. ¼	1,360	1,515	1,829	17		1,850	do	17	do	90 barrels.
190...	34	SE. ¼	1,360	1,511	1,830	10		1,850	do	10	do	125 barrels.
191...	34	SE. ¼	1,400	1,525	1,849	17		1,868	do	17	do	75 barrels.
192...	34	SW. ¼	1,330	1,520	1,848	10		1,860	do	10	do	40 barrels.
197...	35	SW. ¼	1,340	1,510	1,839	12		1,863	do	12	do	70 barrels.
199...	35	NW. ¼		1,510	1,845	30		1,875	do	30	do	27 barrels.
201...	35	NW. ¼		1,585			2,020	2,039	"Mississippi"	10	do	6 barrels.
206...	35	SE. ¼						1,627	1,606–1,627 (stray)	21	Gas	
207...	35	SE. ¼						1,970			Dry	
208...	36	SW. ¼			1,842						do	
210...	36	SE. ¼						1,813	Bartlesville	18	Oil	2 barrels.
211...	36	SE. ¼						1,810	do	18	do	40 barrels.
212...	36	SE. ¼						1,812	do	18	do	10 barrels.
213...	36	SE. ¼						1,910	do	18	do	40 barrels.

T. 29 N., RS. 11 AND 12 E.

By Marcus I. Goldman.

INTRODUCTION.

The geologic work on most of T. 29 N., Rs. 11 and 12 E. (see fig. 1), was done between the beginning of October, 1917, and the end of February, 1918, by the writer, assisted for a short time by Frank Reeves, under the general direction of K. C. Heald, who helped especially in working out the structure in some of the areas where it is more difficult to unravel. Mr. Heald himself mapped the area in the northwestern part of T. 29 N., R. 12 E., as shown on Plate XLIX. The instrument work was done by Elton Rhine and Mary Ware Goldman and for a few days by Frank Reeves.

T. 29 N., R. 11 E., is rather open and rolling except in its northwestern part, which is marked by sandstone escarpments, where higher sandstones come in. As the surface rises in the northern part of T. 29 N., R. 12 E., it becomes rough and more wooded, but the southern part of that township, separated from the northern part by a pronounced escarpment, capped by the Cheshewalla sandstone, is also open and rolling. The proposed line of the Atchison, Topeka & Santa Fe Railway from Pawhuska, Okla., to Caney, Kans., lies just south of these townships, passing through the extreme southeast corner of T. 29 N., R. 12 E.

STRATIGRAPHY.

ROCKS EXPOSED.

The rocks exposed in T. 29 N., R. 12 E., are predominantly shales, but there are a few sandstone beds present and a very minor amount of limestone. The stratigraphic relations of these rocks are shown graphically in figure 46, and the characteristic features of the beds which were most useful in mapping the structure of the townships are briefly described below.

Jonesburg sandstone.—The Jonesburg sandstone is a persistent bed which forms the rim of many of the minor ridges and plateaus in the northwestern part of this area. It is named for its conspicuous exposure on the top of the ridge west of the town of Jonesburg, Chautauqua County, Kans., a short distance to the north of T. 29 N.,

R. 11 E. Its topographic position in this area makes it seem probable that it is the lowest bed of the "Chautauqua sandstone" of Adams.[1] Its physical appearance is not sufficiently characteristic to permit it to be distinguished by this criterion from other sandstones in this area. It can, however, be recognized by its relation to a thin sandstone about 12 feet above it, which generally exhibits fossil imprints, mainly pelecypods and gastropods, among which the strongly ornamented *Astartella* can frequently be observed. Very rarely the fossils of the overlying sandstone appear in the upper part of the Jonesburg sandstone itself, and near the extreme northwest edge of the township surfaces covered with impressions of *Fusulina* were found. In places the top of the Jonesburg sandstone shows a heavy stain of red to yellow ocher, and the tops of the main beds display beautifully preserved linear ripple marks and current marks. However, these same markings have also been observed in other sandstones in the townships discussed in this report, so although they are of local assistance they can not be used as definite criteria for the recognition of this sandstone. Like all the other sandstones of the area, the Jonesburg is of variable thickness. In most localities it is evidently at least 5 to 10 feet thick, but locally, as in the NW. ¼ sec. 17, T. 29 N., R. 11 E., it is 75 feet or more thick.

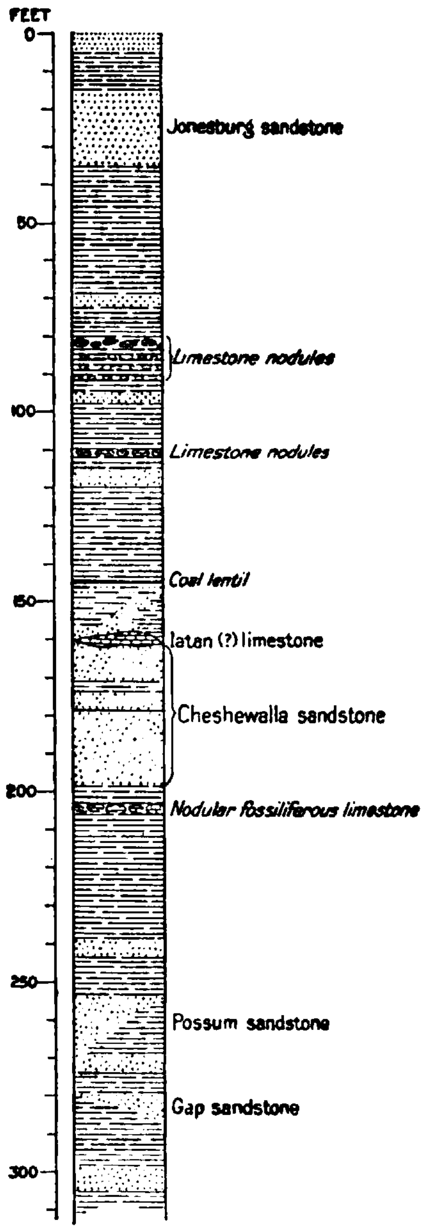


FIGURE 46.—Stratigraphic section showing rocks exposed in T. 29 N., Rs. 11 and 12 E.

Limestone nodules in shale.—A series of layers of limestone nodules was observed in several places from 65 to 100 feet below the top of the Jonesburg sandstone (the upper layer of limestone nodules in fig. 46). These limestone nodules are associated with abundant marine fossils of many kinds, among which Bryozoa are the most easily distinguishable. The nodules are distributed through a layer of about 11 feet in the shale, but the largest ones, averaging some 4 to 5 inches in diameter, occur near the top of

[1] Kansas Univ. Geol. Survey, vol. 3, pp. 58, 59, 1898; vol. 9, p. 107, 1908.

the layer. At approximately the same horizon some white to yellow vesicular calcareous material is in many places disseminated through the shale. This is undoubtedly the product of concentration of limy material in the shale by surface waters, so that it does not represent a definite horizon, but it may be easily confused with scattered nodules of limestone, weathered out of the shale. The layer of limestone nodules was used only in working out the complicated structure along the fault in sec. 16, T. 29 N., R. 11 E. Limestone nodules at a lower horizon were found in sec. 31 near the west edge of T. 29 N., R. 11 E., and are said to be represented by a more persistent limestone farther west. Between these limy series and the Jonesburg sandstone is shale with some lenticular bodies of sandstone.

Iatan (?) limestone.—The Iatan (?) limestone, which lies from 100 to 180 feet below the top of the Jonesburg sandstone, is an impure limestone, in some places as much as 7 feet thick and in others represented merely by impressions of fossils on the upper surface of the underlying sandstone. It seems very probable that this is the continuation of the "Kickapoo limestone" of Kansas (now considered as unquestionably the same as the Iatan limestone of Missouri), though unfortunately the "Kickapoo limestone" is not shown on any of the available maps of that part of Kansas which is just north of T. 29 N., R. 11 E. However, the outcrop of this limestone at the Kansas boundary of the township is intermediate in position between the outcrops of the Oread and Stanton and Plattsburg limestones, and the general description given in the Kansas report conforms to what is found in T. 29 N., R. 11 E., in Oklahoma. The Kansas report [1] describes the limestone as "found in places here and there"; correlates it with the "lenticular limestone of Willow Creek described by Schrader," notes its frequent variations in thickness, and says that "in some places it is scarcely recognizable." This variation in thickness is characteristic of the Iatan (?) limestone in the townships under discussion. It is probably best developed in sec. 16, T. 29 N., R. 11 E., but it is also prominent in the southeastern part of sec. 22 and the northwestern part of sec. 27, T. 29 N., R. 11 E. In the southwest corner of sec. 34, T. 29 N., R. 11 E., it attains a thickness of 7 to 8 feet, the greatest thickness noted in this area. Over most of the rest of the area it is represented only by shell impressions in sandstone, but near the middle of the boundary between secs. 25 and 26, T. 29 N., R. 11 E., it appears in an isolated lens about 5 feet thick and 100 feet long. In T. 29 N., R. 12 E., it has been noted only near the west edge, but fossils in the upper part of the underlying sandstone are persistent throughout the township.

[1] Kansas Univ. Geol. Survey, vol. 9, p. 106, 1908.

Fusulina is the most characteristic and easily recognizable fossil in the limestone throughout this area. It is least conspicuous in sec. 16, T. 29 N., R. 11 E., where the limestone consists more predominantly of other shells, including brachiopods and corals. Along Skull Creek *Fusulina* practically makes up the limestone and is abundant in the basal 3 or 4 feet of the overlying sandstone.

Cheshewalla sandstone.—The Cheshewalla sandstone, named by Winchester and Heald,[1] from Cheshewalla Creek, in T. 25 N., R. 10 E., immediately underlies the Iatan(?) limestone. It is very similar in general appearance and composition to the other sandstones in this region, being composed of very fine, moderately well rounded translucent grains of quartz cemented with varying degrees of firmness into beds which are in some places thick and massive and in others finger out into thin flagstones, with intervening lentils of shale. The upper portion of this sandstone is commonly fossiliferous, pelecypods and gastropods being particularly abundant. The fossils are largely confined to the thin flaky beds, but here and there imprints of *Fusulina* and other forms are found in the upper surface of the more massive members. The thickness of the bed varies from place to place. The maximum thickness is probably more than 50 feet, but in some parts of T. 29 N., R. 12 E., the bed is less than 20 feet thick. In T. 29 N., R. 12 E., occur a number of more or less distinct heavy benches from 2 or 3 to 10 feet thick, separated from the main overlying sandstone by thin layers of shale. These benches are particularly numerous and heavy along the sides of the Coon Creek valley, in the northern part of the township.

Possum sandstone.—The Possum sandstone is the first sandstone of prominence below the Cheshewalla sandstone in T. 29 N., R. 11 E. Between it and the Cheshewalla is a shale member usually 75 to 100 feet thick. This shale member contains a number of lenticular sandstones which occupy about 50 feet of the interval, but none of these could be traced for any appreciable distance. The Possum sandstone is therefore equivalent to a part of the Revard sandstone,[2] probably lying at or being near the top of that sandstone.

In the western part of its area the Possum sandstone is a soft massive bed, the freshly broken surface of which shows some discontinuous bedding lines and is generally covered with rusty or blackish specks as much as an eighth of an inch in diameter. To the east in sec. 32, T. 29 N., R. 12 E., the bed thins abruptly, changes to a hard, platy, greenish limy or sideritic sandstone only a few inches thick, and within a few feet disappears entirely. This accounts for the fact that the line on Plate XLIX indicating the outcrop in that section does not close. Similar greenish sideritic material was found

[1] Winchester, D. E., and Heald, K. C., U. S. Geol. Survey Bull. 686-G, p. 61, 1918.
[2] U. S. Geol. Survey Bull. 686-G, pp. 61-63, 1918; Bull. 686-I, p. 94, 1918.

overlying the Possum sandstone at several places, and about 1,000 feet south of the southwest corner of T. 29 N., R. 12 E., about 1 foot of this material is overlain by a few inches of nodular limestone made up mainly of fossils, including many brachiopods and large crinoid stems.

The Possum sandstone is named from the occurrence as a prominent ledge along the sides of Opossum Creek in the southeast corner of T. 29 N., R. 11 E.

Gap sandstone.—The Gap sandstone is named from its occurrence at the top of Gap Ridge, in the southeast corner of the area mapped. The gap, locally known as Osage Gap, through which pass a high road and the branch of the Atchison, Topeka & Santa Fe Railway between Pawhuska, Okla., and Caney, Kans., cuts through this ridge just east of the southeast corner of T. 29 N., R. 12 E., as shown on the map. In its exposure at the gap the sandstone is 10 feet or less thick, but it thickens to the north, where it forms the surface of most of the Ramsey anticline. This sandstone, like the Possum sandstone, is equivalent to a part of the Revard sandstone of neighboring townships. Like most of the other sandstones in this part of the section, it is very lenticular. It was not recognized to the west across the valley of Coon Creek, in sec. 32, T. 29 N., R. 12 E., and it can be seen to pinch out within half a mile to the south of the gap, in and just east of the northeast corner of T. 28 N., R. 12 E.

ROCKS NOT EXPOSED.

Inspection of the map (Pl. XLIX) shows that except in the small field in the north-central part of T. 29 N., R. 11 E., and in the northwestern part of sec. 17 of the same township, drilling in the area under discussion is very small in amount and widely scattered. So far as known only eight wells in T. 29 N., R. 11 E., and three in T. 29 N., R. 12 E., have reached the "Mississippi lime." Of several of these wells the record is very incomplete, in some logs only the "Mississippi lime" being recorded. Those having more complete records all started within a few feet of the top of the Cheshewalla sandstone. Below are given the average approximate distances below the top of that sandstone of the principal strata encountered:

Approximate distances below top of Cheshewalla sandstone of principal strata encountered in wells in T. 29 N., Rs. 11 and 12 E.

	Feet.
Sand with a little gas and some water	250–350
Gas and water sand	550
Red or Stray sand (so-called "Peru" sand of some drillers)	900–1,000
Big lime, sometimes with a strong flow of gas (20–90 feet thick, average about 50 feet)	1,000–1,050
"Oswego lime" with interbedded black shale (about 75–125 feet thick)	1,310
"Mississippi lime" (greatest thickness penetrated 123 feet)	1,650–1,780

A number of these deep wells obtained considerable gas and a showing of oil in the "Mississippi lime," but the available records report a workable yield of oil from only one, the 225-barrel well at the south edge of the SW. ¼ sec. 31.

Most of the oil and gas produced in the area appears to come from a sand called by the drillers the "Peru" sand, although it does not coincide with the true Peru sand. It lies at an average distance of 950 feet below the top of the Cheshewalla sandstone, ranging from about 900 feet to a little over 1,000 feet, but usually between 950 and 1,000. Its thickness seems to be about 45 feet. It does not appear to be recorded in any of the wells drilled to the "Mississippi lime," unless it is represented by 45 feet of water-bearing "lime" found at a depth of about 935 feet below the Cheshewalla sandstone in a well in sec. 30, T. 29 N., R. 12 E., and 4 feet of "lime" at a depth of 910 feet below the Cheshewalla in a well in the NE. ¼ sec. 20, T. 29 N., R. 11 E. The true Peru sand lies below the Big lime, but the Big lime, so far as noted, is never recorded above the so-called "Peru" sand. Probably this "Peru" sand occupies approximately the same horizon as the No. 7 sand, from which oil is obtained in T. 29 N., R. 10 E.[1] It is probably the equivalent of the Red or Stray sand, which is one of the important producing sands in Chautauqua County, Kans.[2] The logs of three of the wells that go down to the "Mississippi lime" in T. 29 N., Rs. 11 and 12 E., record a sand about 20 feet thick which is believed to be the true Peru sand. They all agree in placing it at a depth of about 1,230 feet below the Cheshewalla sandstone and not more than 10 feet below a heavy lime which in one of these logs is called the Big lime. This lime overlying the true Peru sand is

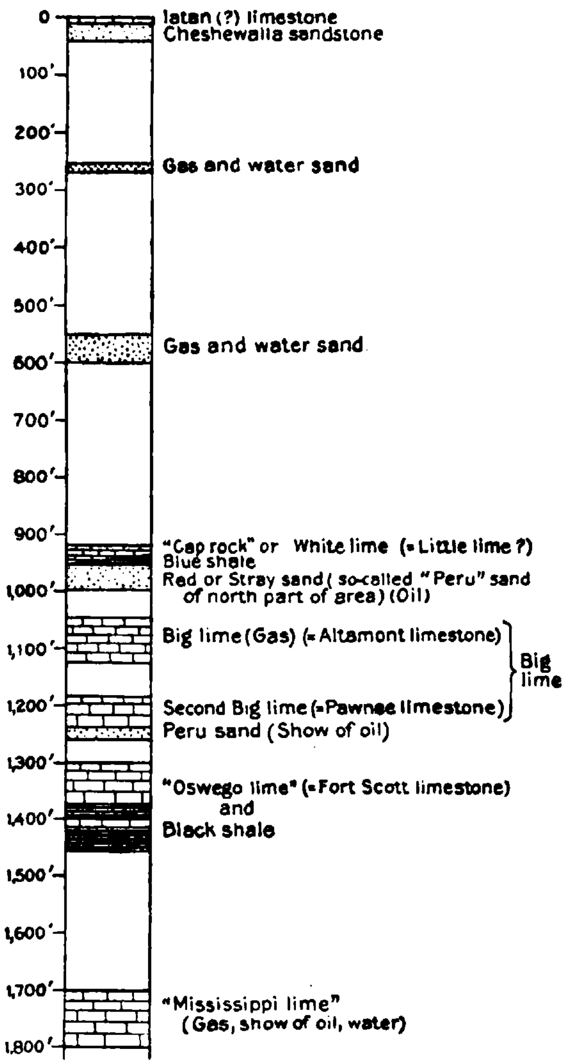


FIGURE 47.—Generalized stratigraphic section of rocks encountered in wells in T. 29 N., Rs. 11 and 12 E.

[1] See U. S. Geol. Survey Bull. 686–F, pl. 9, column 6, 1918.
[2] See Kansas Geol. Survey Bull. 3, pp. 245–246, 1917.

undoubtedly the lower member of the Big lime, sometimes called the Second Big lime in logs of wells in this vicinity. The heavy limestone shown directly above it in the diagrammatic section (fig. 47) is undoubtedly the upper member of the Big lime, generally called merely the Big lime. In one of the three deep wells in T. 29 N., Rs. 11 and 12 E., the true Peru sand gave a show of oil and in another a little gas. The fact that all these deep wells are in the southern part of the area and that none of them record any trace of what might be the higher Red or Stray sand may indicate that that sand disappears to the south. The bed of lime shown just above the Red or Stray sand in figure 47, where recorded at all, generally appears merely as "lime" or "cap rock" in the logs of wells in T. 29 N., Rs. 11 and 12 E., but it is believed to be the equivalent of the bed called the Little lime farther south.[1]

Operators in these townships are strongly urged in all areas where the shallower sands are found to be productive to extend operations to the "Mississippi lime" at a depth of about 1,700 feet and to penetrate it for at least 200 feet.

STRUCTURE.

GENERAL ATTITUDE OF THE BEDS.

The general north to northwest dip that characterizes this region is most evident and uniform along the eastern tier of sections of T. 29 N., R. 12 E., and the eastern 1 to 1½ miles of T. 29 N., R. 11 E. Over most of the remaining area in these townships it is modified by many minor

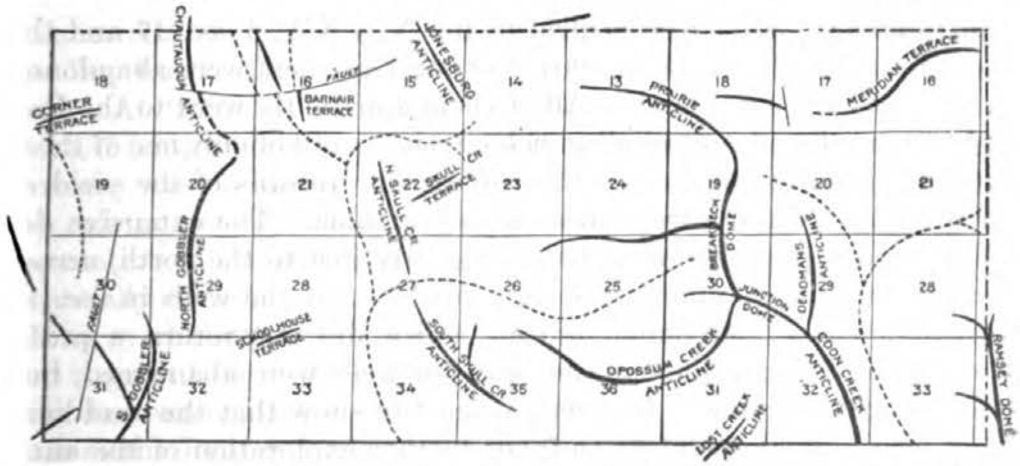


FIGURE 48.—Diagram showing approximate position of axes of folds in T. 29 N., Rs. 11 and 12 E. Dotted lines indicate synclines.

folds and several faults. To a certain extent these minor structural features may be grouped along certain lines. (See fig. 48.) These lines are in two sets, one of which runs approximately north to north-northwest, the other approximately east. Of the northerly lines three or four groups can be recognized. The westernmost runs south

[1] See, for instance, U. S. Geol. Survey Bull. 686–T, pl. 42, facing p. 262; Bull. 686–V, pl. 47, facing p. 300.

from the Chautauqua anticline at the State line in the center of sec. 17 T. 29 N., R. 11 E., to the southern part of sec. 29, and farther south where it is offset toward the west in the South Gobbler axis. Another structural line lies along the east side of the valley of Hickory Creek east of the center of T. 29 N., R. 11 E., starting from the Jonesburg anticline, in the northern part of sec. 15, and running through the North Skull Creek anticline into the south Skull Creek anticline, where it bends toward the east. The most nearly continuous axis is that running from the summit of the Prairie anticline at the center of the south edge of sec. 18, T. 29 N., R. 12 E., south to the Junction dome, in sec. 30, where one of the axes of the east-west set connects it with the north-south axis connecting the Coon Creek and Deadman's anticlines, in secs. 32 and 29, respectively.

A brief discussion of the individual structural features follows.

CHAUTAUQUA ANTICLINE.

The Chautauqua anticline lies in the northern part of sec. 17, T. 29 N., R. 11 E., but the portion within this township is probably merely the south end of a fold lying to the north, across the line in Kansas. That part of it which is more than about three-eighths of a mile south of the State line is broken by transverse faults and synclinal folds which may tend to cause local "dry" areas. The steepness of the flanks of this anticline, combined with a good closure, is favorable for the trapping of any oil that might work its way up the flanks, but they cover so small an area that the amount of oil is likely to be small.

A number of wells were drilled in the N. ½ NW. ¼ sec. 17 and the the NE. ¼ NE. ¼ sec. 18 in 1904, but most of them were abandoned in the next five years or so. All of them apparently went to the Red or Stray sand, and almost all struck oil, the record of only one of them showing nothing but gas. Unfortunately no records of the yield of oil from any of these wells has been obtainable. The extensive development of pumping oil wells during 1917 just to the north, across the line in Kansas, makes it seem probable that the wells in sec. 17 yielded a steady but small output which did not return a profit under market conditions at the time the wells were abandoned, but which might pay now. It serves at least to show that the sand here is oil bearing and therefore to favor further exploration of the anticline to the south along this general axis. The present production on this anticline in Kansas serves further to indicate that no great amount of water was let into the sand when the oil wells were abandoned. How nearly the old wells were exhausted at the time they were abandoned can not be determined from the information available, but it does not seem probable that the sand adjacent to them was drained in the five years or so during which they yielded. The indications, therefore, favor resuming operations on this fold—if not in the same locations then in the untried portions. For this purpose the anticline may be regarded as extending to the south line of sec. 17.

There is some doubt about the structure of what is regarded as the southern extension of this anticline and of the area lying between this and the North Gobbler anticline, because it has been worked out from a combination of the elevations obtained on a narrow ridge of the Jonesburg sandstone and on a ledge of the Cheshewalla sandstone. The two beds are separated from each other by a broad area in which no outcrops could be found, and at the same time the correlation of elevations from one bed to the other is complicated by the fact that there is evidently a very great and abrupt convergence between the two beds, of which the exact amount can, under the circumstances, only be estimated. A well drilled in the area between the outcrops of the two beds, in the NE. ¼ sec. 20, at the base of the east side of the ridge capped by the Jonesburg sandstone, should have encountered the Cheshewalla sandstone; yet there is nothing in the record to indicate it. It is, however, almost impossible that the Cheshewalla sandstone, which is a 15 to 20 foot bed at its outcrop about half a mile to the east, should be completely absent at this well.

The well, which is just north of the small domelike summit of the anticline at the northeast edge of sec. 20, T. 29 N., R. 11 E., obtained large flows of gas at two horizons above the "Mississippi lime"—one about 600 feet below the top of the Cheshewalla sandstone, the other in a limestone only 4 feet thick at about 910 feet below the Cheshewalla sandstone and some 700 feet above what is probably the Big lime. This may be the equivalent of the Red or Stray sand. At 10 feet down in the "Mississippi lime," which was entered at 1,737 feet, there was a show of oil; at 20 feet below the top of the lime gas was obtained. Large flows of gas would be expected from the relation of the hole to the structure, and therefore the representation of the structure on the accompanying map is probably essentially correct.

The good showings obtained from the "Mississippi lime" in this well suggest that in the extension of development on the Chautauqua anticline exploration should not be limited to the shallower beds, such as the Red or Stray sand, but should be continued to penetrate 200 to 300 feet into the "Mississippi lime."

The most favorable location for a first deep test of this kind would probably be near the productive shallow wells drilled about 1904, especially in the NE. ¼ NW. ¼ sec. 17, T. 29 N., R. 11 E. Here the "Mississippi lime" should be entered at a depth of about 1,800 to 1,900 feet. If tests in this vicinity prove successful, it may be found that the deeper structure is more uniform and the folding more extensive than that at the surface, and development might be extended over a greater area than is indicated by the surface structure contours.

Since field work in this township was completed two wells have been drilled on the east edge of the NE. ¼ NW. ¼ sec. 18, of which one gave a showing of oil and the other was dry. As these wells are practically in the syncline bounding the Chautauqua anticline on the west, the unfavorable result accords with the structure.

NORTH GOBBLER ANTICLINE.

The North Gobbler anticline is essentially a southward extension of the Chautauqua anticline, but it is pinched off by two synclinal reentrants in the NE. ¼ sec. 20, T. 29 N., R. 11 E., and may be regarded as extending from the NW. ¼ SE. ¼ sec. 20 through the center of sec. 29 to the south boundary of that section. It is a well-defined, regular, broad fold, with a gathering ground on the west flank about three-fourths of a mile wide. It appears to pitch slightly toward the south.

The only well that has been drilled on this anticline is in the SW. ¼ NW. ¼ sec. 29, too far down the west flank toward the small syncline which bounds it. This well struck gas in the top of the "Mississippi lime" and oil some 40 feet deeper; but the initial production was small, and the well, when seen early in 1918, was connected to yield gas only. Neither this well nor any of those adjacent to it in sec. 31 report any oil or gas from the Red or Stray sand. Nevertheless, it seems probable that the yield from that sand in the NW. ¼ sec. 17 might be duplicated in the two sections to the south, and a more favorable location on the anticline might encounter larger quantities of oil in the "Mississippi lime." Locations in the NE. ¼ and SE. ¼ NW. ¼ sec. 29 are suggested as the most favorable for tests. The "Mississippi lime" should be reached at depths of 1,700 to 1,750 feet.

SOUTH GOBBLER ANTICLINE.

The axis of the broadly dome-shaped South Gobbler anticline runs from about the quarter corner between secs. 29 and 30, T. 29 N., R. 11 E., to the quarter corner between secs. 31 and 32, whence it swings off to the southwest, crossing the south township line about a quarter of a mile west of the southeast corner of sec. 31. The principal part of the anticline lies in the SE. ¼ sec. 31; the west flank of the tonguelike northern part is narrower, more irregular, and therefore less favorable for the accumulation of oil. A north-northeasterly fault that bounds the entire west flank of the anticline may have limited the gathering ground for oil. At the time the area was mapped only two test holes had been drilled on this structure. The evidence that they afford is uncertain. One was in the NE. ¼ SE. ¼ sec. 31, slightly east of the axis, which, though somewhat less favorable than a location on the west side of the axis, is still a good position. Near the top of the "Mississippi lime" oil was encountered, which at a slightly greater depth was followed by water, and when seen early in 1918 the well was blowing off gas and salt water. Furthermore, gas was encountered in sands 555 feet and 630 feet and in the Big lime 1,030 feet below the top of the Cheshewalla sandstone, and oil and water were found in a sand about 680 feet below the top of the Cheshewalla. The occurrence of gas at several horizons is to be expected from the position of the well near the top of the fold. The other test hole completed at the time the area was being studied is in the SW. ¼ NE. ¼ SE. ¼ sec. 30. This is well down the west flank of the plunging north end of the anticline. It obtained only a showing of oil, which is all that would be expected from its position with relation to the structure.

Since the field work in this township was completed two other wells have been reported. They are near the east edge of the SE. ¼ NE. ¼ sec. 31. The more southerly of the two, lying nearer the summit of the anticline, is said to yield 25 barrels of oil a day, and the other 10 barrels, from a bed at about 1,700 feet, presumably the "Mississippi lime." The locations are good, though somewhat too near the synclinal reentrant in the NE. ¼ sec. 31. The indications they give for further developments are favorable and agree with what would be expected from the structure as represented. Other favorable locations for further tests would be in the NW. ¼ and SW. ¼ SE. ¼ sec. 31, on the west flank of the main structure.

EXTENSION OF WEST TURKEY CREEK ANTICLINE.

In the SW. ¼ sec. 30 and the NW. ¼ sec. 31, T. 29 N., R. 11 E., there may be a small dome. It is shown on the map in broken lines, on account of the poor surface exposures here, which make the structure uncertain. If correctly mapped it is essentially merely a southeastern extension of the West Turkey Creek anticline, in T. 29 N., R. 10 E.,[1] from which it is separated by a small synclinal pinch. Considered in connection with the adjacent fold in T. 29 N., R. 10 E., it is evidently very insignificant, but if the productive area on the West Turkey Creek anticline is carried in this direction it might be extended to include this small dome. As the surface of this dome lies about 120 feet below the surface of the West Turkey Creek anticline, the Red or Stray sand should be encountered at a depth of about 950 feet and the "Mississippi lime" at about 1,650 feet.

[1] U. S. Geol. Survey Bull. 686-F, pp. 50-51, 1918.

ANTICLINE IN SW. ¼ SEC. 31, T. 29 N., R. 11 E.

Some development work has been done on the southeast flank and summit of the small, sharp, elongated northeasterly anticline in the SW. ¼ sec. 31, T. 29 N., R. 11 E., with very irregular results. A hole near the crest of the fold had an initial yield of 1,500,000 cubic feet of gas a day from the "Mississippi lime"; of two farther down the southeast flank, one was reported to have an initial daily production of 225 barrels of oil from the "Mississippi lime," but the other, 600 feet west of it, yielded only 8 barrels from the same lime and was abandoned. A number of others were dry or yielded only moderate amounts of gas. These results may indicate local variations in the porosity of the "Mississippi lime" or the presence in this sharp little fold of small faults, which perhaps can not be detected at the surface but which nevertheless cut off the flow of oil into parts of the anticline. The shallower sands apparently do not yield oil or gas here. In spite of the great depth to the "Mississippi lime," the fact that a 225-barrel well was obtained on the southeast flank makes it worth while to do further drilling on the more favorable northwest flank of this fold, also on the northeast end in the W. ½ NE. ¼ SW. ¼ and the E. ½ NW. ¼ SW. ¼ sec. 31. Beyond this township the axis of the anticline bends more to the south and extends only about half a mile into the northwest corner of T. 28 N., R. 11 E.

CORNER TERRACE.

A well-defined terrace in the SW. ¼ sec. 18, T. 29 N., R. 11 E., is here called the Corner terrace. The axis runs about due east and pitches west. It has a pronounced summit at its east end, represented by a single closed contour, which gives it a domelike character at that end. From this summit it expands toward the west and southwest. Its position between the Chautauqua anticline on the east and the Turkey Creek anticline on the west, in T. 29 N., R. 10 E., is favorable, offering the possibility of production from at least three beds—the Red or Stray sand, which is to be looked for at about 1,100 feet; the Peru sand, at about 1,200 feet; and the "Mississippi lime," at about 1,750 to 1,800 feet.

TERRACES WEST OF HICKORY CREEK.

Along the west side of Hickory Creek in the tier of sections from 16 to 33 there is a prevailing easterly dip toward Hickory Creek, interrupted by minor folding along axes more or less transverse to this. The east slopes are everywhere relatively short, so that the amount of rock from which oil might accumulate in the upper parts of the slopes is small, and any large production is therefore not to be expected. The writer believes that the steepness of these folds on their slopes toward Hickory Creek may be exaggerated somewhat by slumping, not in blocks but as a whole bed, of the heavy Cheshewalla sandstone, as a result of the cutting away and slow sliding toward Hickory Creek of the underlying shales, which are in places at least 70 feet thick.

In the valley of Hickory Creek, which runs approximately due north throughout the center of T. 29 N., R. 11 E., alluvium conceals the structure, but it is evident that the valley is underlain by strong synclines with possibly one or more approximately north-south faults.

A brief discussion of the principal individual folds on the general east dip along the west side of Hickory Creek follows.

BARNAIRE TERRACE.

The Barnaire terrace is a very low, flat-topped terrace whose axis runs about due north through the center of the S. ½ sec. 16, T. 29 N., R. 11 E. Although it is not a pronounced structural feature, it is very significant because of the extensive development that has taken place on and around it. The structure in this area is rather difficult to determine on account of the prairie which covers a large part of the area and on account of the valley of Hickory Creek just east of the terrace. There is a practically continuous group of producing wells in the SE. ¼ sec. 16, the SW. ¼ sec. 15, and the NE. ¼ sec. 21. The Barnaire terrace itself has a very slight reversal of dip on its east flank, beyond which the flattening of the beds appears to continue eastward to form practically a westward nose of the small Jonesburg anticline in sec. 15. This structure accounts satisfactorily for the production in secs. 15 and 16. The producing wells in the NE. ¼ sec. 21, however, fall in an area represented as having synclinal structure. Although the mapping of this area is uncertain, the structure being therefore represented by broken contours, the discrepancy between the output that has been obtained and the absence of oil that would be expected is nevertheless noteworthy. The oil is obtained entirely from the so-called "Peru" sand (probably the Red or Stray sand, as explained on p. 334), which is encountered at a depth of about 950 feet, the surface being mostly formed by the top of the Cheshewalla sandstone. The initial production is nowhere large, approximating in most of the wells 20 barrels a day, but on account of the great number of successful wells within a small area and the small cost of the wells it probably yields a considerable profit. Many of the wells have been pumped for about eight years. This is significant for the entire adjacent region as indicating that structural features that appear weak at the surface may offer favorable sites for drilling. The good production obtained in the shallow sand here makes it desirable that test holes be drilled through to the "Mississippi lime," which should be entered at a depth of about 1,700 feet.

On the north the Barnaire terrace is bounded by a roughly east-west fault against which the downthrust beds on the north side are strongly folded, apparently on a northward continuation of the axis of the terrace. There is in this region some evidence of a general tendency for structural features to be steepened in this way where they are crossed by faults. Something of the same kind appears, both in the next syncline and in the next anticline to the west, along what is probably the same fault. In all these places the steepening is on the downthrown side of the fault, as if the beds had been crowded as a result of a shortening of the arc occupied by them. The anticline mentioned forms a pronounced hill at the surface, but it may be too small to yield a commercial production. Apparently the same axis continues northward to the center of the north edge of the section and doubtless beyond the State line into Kansas. It is quite possible that the productive area on the Barnaire terrace may be found to continue along the northward extension of its axis. In that direction, however, the surface of the central part of the terrace is formed by the Jonesburg sandstone, which lies about 160 feet above the Cheshewalla sandstone, so that there would be that additional distance to go in drilling to the same beds as underlie the Barnaire terrace.

SCHOOL HOUSE TERRACE.

A terrace with east-west axis and easterly pitch on the west edge of Hickory Creek, in the northern part of sec. 33 and southern part of sec. 28, T. 29 N., R. 11 E., is here called the School House terrace. It may have a small closure on its east end, but the exact form of its top is uncertain, on account of the prairie which covers most of it. It has not been tested for oil but appears to be favorable. The Red or Stray sand may not extend as far south as this, but if it is absent production might still be expected from the Peru or some other sand below the Big lime or from the "Mississippi lime." As the Cheshewalla sandstone caps most of the terrace the base of the Big lime should lie at about 1,035 feet below the surface and the top of the "Mississippi lime" at about 1,700 feet. The most favorable position for a test would be about in the SE. ¼ SE. ¼ SW. ¼ sec. 28. To a certain extent this terrace is an easterly extension of the nose running eastward from the South Gobbler anticline at the east edge of the NE. ¼ SE. ¼ sec. 31, and if oil is obtained near the location suggested for a test it might be found to continue westward to the summit of the South Gobbler anticline.

ANTICLINE IN SEC. 33, T. 29 N., R. 11 E.

The tonguelike northeasterly anticlinal ridge in the southeast corner of sec. 33 is essentially a northward extension of a strong upfold just to the south, in sec. 4, T. 28 N., R. 11 E. Its steep east flank seems to offer favorable conditions for the accumulation of oil, though the northwest slope is rather flat and short. In any case testing of it should await developments on the more favorable southward extension in T. 28 N., R. 11 E.

ANTICLINES EAST OF HICKORY CREEK.

Interpretation of the structure directly east of the valley of Hickory Creek is made difficult by the lack of knowledge of what underlies the valley alluvium. As stated above, however, the beds are pretty certainly either synclinal or faulted. In either case the gathering ground, from which oil might have been accumulated, in the upper parts of the small synclines and domes along the west side of the creek is limited, so that large yields are not to be expected, but steady yields of small quantities, like those found in sec. 16, T. 29 N., R. 11 E., may be obtained. The principal individual folds are discussed below.

JONESBURG ANTICLINE.

The Jonesburg fold differs from the others along the east side of Hickory Creek in that the synclinal depression along that creek flattens and practically disappears at this north end, so that, as explained above, structurally the Jonesburg anticline is essentially continuous with the Barnaire terrace on the west side of the creek. This continuity is also indicated by the distribution of the wells. It is a low, flat, broad terrace-like anticline whose axis trends about north-northwest and runs through the NE. ¼ and the N. ½ SE. ¼ sec. 15, T. 29 N., R. 11 E. The highest part is in the SW. ¼ NE. ¼ sec. 15, whence a nose extends slightly south of west toward the west edge of the section. The productive area in the SW. ¼ sec. 15, referred to above in connection with the Barnaire terrace, is on the flank of this anticline, and there is no apparent reason why it should not be found to extend over the entire northern three-quarters of the section. Three wells were drilled in 1903 along the western part of the north line of the section. All these wells produced gas (amount not recorded) from a sand that was encountered at about 950 feet and therefore is apparently the same as that from which oil is obtained to the south and southwest. The interpretation of the occurrence of gas instead of oil here depends somewhat on knowledge of the structure to the north and northwest. If there is an extensive slope in that direction oil may occur farther down on it, while gas has accumulated in this upper part. The other possibility is that here, as in some other areas, the sand is gas bearing without reference to any structural condition. Most of the wells in the SW. ¼ sec. 15 were completed in 1904 and 1905 and are at present pumping about half a barrel a day each. Records of their initial production are not available. Most of the productive area lies south of the small east-west fault, the holes directly north of it being dry or very small producers. This condition may be due to the interception of oil from lower parts of the slope on the south by the fault. All these wells appear to be obtaining their oil from the Red or Stray sand. The fact that a dry hole was put down just north of the fault suggests the possibility that the southern part of the anticline just north of the fault in the eastern part of the section may also be unfavorable, but it does not seem probable that this would affect the northern part of the anticline in the northwestern part of the section, as oil in this part would gather from the west flank.

NORTH SKULL CREEK ANTICLINE AND TERRACE.

The structure of the North Skull Creek anticline is somewhat indeterminate, the rocks being largely concealed by grazing land with little topographic relief. It is believed, however, that here, as in many other places, there is a general agreement between topography and structure and that the flat prairie corresponds in a general way to the terrace-like structural features shown on the map.

The anticline is long and narrow, and its axis trends about north-northwestward from the center of the N. ½ sec. 27 to the SE. ¼ NW. ¼ sec. 22, T. 29 N., R. 11 E. It forms the western limit of the east-northeastward-trending North Skull Creek terrace. It has a pronounced summit at its south end and a broader, flatter one at its north end. The short west flank of the anticline limits the gathering ground for oil, so that a large production is not to be expected, but pumping wells yielding 5 to 20 barrels a day, like those in adjacent parts of secs. 15, 16, and 21, may be obtained. This result is all the more likely, as the presence of several such wells in the northwest corner of sec. 22 shows the tendency already noted in this area (see p. 341) for even structural features that are not represented as anticlinal to yield oil. It is believed, however, that the best yield should be obtained from the sharp little dome on the south end of the anticline, in the SE. ¼ NE. ¼ NW. ¼ and the NE. ¼ SE. ¼ NW. ¼ sec. 27.

A conductor slowly overflowing oil in about the SW. ¼ NE. ¼ NE. ¼ sec. 27 (no record of this well could be obtained), on the edge of the syncline, just east of this little dome, is a favorable indication. On these folds, as elsewhere, there is also a good possibility for production from the "Mississippi lime," which should be reached at about 1,750 feet. The best positions for deep tests would probably be those just indicated, on the dome at the south end of the anticline.

There is a record of a dry hole drilled to the "Mississippi lime" at 1,700 feet in the NW. ¼ sec. 27. This is probably the one shown on the location map of the Bureau of Mines as in the southwest corner of the SW. ¼ NW. ¼ NW. ¼ sec. 27, a position which would place it in the syncline shown on the accompanying structure map (Pl. XLIX). In that position the failure is what would be expected from the structure.

SOUTH SKULL CREEK ANTICLINE.

The South Skull Creek anticline is essentially a southward extension of the North Skull Creek anticline from which it is separated by a rather deep synclinal lobe. The axis runs northwestward about the center of the S. ½ sec. 35, crosses the west edge of that section about an eighth of a mile north of the west quarter corner, and thence bends north-northwestward toward the North Skull Creek anticline. Along this axis two summits may be distinguished—an elongated one along most of the axis in sec. 35 and a terrace-like expansion in the SE. ¼ sec. 27. In the W. ½ NW. ¼ sec. 35 a branch bends off to the north to a small sharp dome in the NW. ¼ NW. ¼ sec. 35. If the interpretation of the covered portion along the east side of Hickory Creek in the central part of sec. 34, represented on the map by broken lines, is correct, this is one of the most promising folds in T. 29 N., R. 11 E. The broad west flank, extending half to three-quarters of a mile from the axis, with a difference of elevation of 60 feet in 3,000 feet, affords a large gathering ground for oil, and the summits are well defined. No faults of any importance appear to break the continuity of the anticline. No drilling is known to have been done on this anticline. The Cheshewalla sandstone is the highest bed over most of this area, except in the southern and eastern parts of the W. ½ sec. 35, where the valley bottom is about 60 to 75 feet below the top of that sandstone. The Red or Stray sand probably does not extend this far south. If it does, however, it should be looked for at a depth of about 950 to 1,000 feet. In any case oil might be expected from the Peru sand at about 1,200 to 1,250 feet and from the "Mississippi lime" at about 1,700 to 1,750 feet. There are many good locations for a test, but perhaps the best would be between the main axis and the small branch north dome in the NW. ¼ SW. ¼ NW. ¼ sec. 35.

REMAINDER OF T. 29 N., R. 11 E.

The remainder of T. 29 N., R. 11 E., to the east shows few structural features of importance. Such as there are consist mainly of terrace-like westward extensions from anticlines in T. 29 N., R. 12 E., and may best be considered in connection with those anticlines. (See below.) Separate mention, however, may be made of a small east-west anticline whose summit lies in Kansas, just north of the north corner of secs. 13 and 14, T. 29 N., R. 11 E. The south flank of this fold within this township consists of a broad, gentle slope, which might afford some favorable locations at the north edge of the sections, but the production would probably be small, like that of the area on and adjacent to the Barnaire terrace, in sec. 16.

ANTICLINES AND DOMES IN T. 29 N., R. 12 E.

In T. 29 N., R. 12 E., may be recognized an unusually well defined anticlinal axis which extends northward from the summit of the anticline in T. 28 N., R. 12 E., crosses the south line of sec. 32 about an eighth of a mile west of the southeast corner of that section, and bends westward to the Junction dome, in the center of the east half of sec. 30, with a branch that continues its northern direction extending into the Deadman's anticline in the center of the N. ½ sec. 29 and the S. ½ sec. 20. From the Junction dome the main axis again turns due north, continues through the Breakneck dome to the Prairie anticline, in the northern part of sec. 19, turns westward, and continues practically due west into the terrace-like extension of the Prairie anticline in the northeastern part of T. 29 N., R. 11 E. Similar to the westward extension of the main axis beyond the Prairie anticline are axes running westward into T. 29 N., R. 11 E., into terrace-like extensions of the Breakneck and Junction domes, and a fourth such westward-trending axis may be recognized as an extension of an axis running southwestward from the Junction dome into the terrace-like Opossum Creek anticline, in the northwestern part of sec. 31, T. 29 N., R. 12 E., and the northeastern part of sec. 36, T. 29 N., R. 11 E. A brief discussion of the individual folds along these axes follows.

COON CREEK ANTICLINE.

The Coon Creek anticline lies mostly in sec. 32. On the map almost the entire east flank of this fold is represented by broken lines, which carry the structure across the valley of Coon Creek, where there are practically no rock exposures. There is in that area the double possibility of error in determining how the beds on the two sides of the creek are related to each other and of making wrong assumptions as to the connection of the structure on the two sides. It is only at the north end of the anticline that a small eastward reversal of dip could actually be observed. It is possible, therefore, that the contours continue straight across Coon Creek instead of forming the strong synclinal reentrant shown, or that a fault runs along the west edge of Coon Creek here and that the reversal of dip observed is the dragging down of the beds along such a fault. Finally, the possibility that the apparent reversal of dip is really slumping of the heavy sandstones on the thick masses of shale which underlie them in this steep west bank of Coon Creek must be considered. If the structure is correctly represented this anticline has several very favorable features. Its west flank is steep and about 1 mile broad, and the summit is pronounced. However, as the summit lies in T. 28 N., R. 12 E., it is considered in the discussion of that township. The part in T. 29 N., R. 12 E., is less favorable on account of the northward pitch here and the syncline in the northeastern part of sec. 31, which cuts into the west flank and greatly reduces the gathering ground for oil. Perhaps the most favorable part of this end of the anticline is the terrace-like expansion at the north end, in the southwestern part of sec. 29. A good location for a test hole on this part of the fold would be about the center of the SW. ¼ SW. ¼ sec. 29. No development work is known to have been done on this anticline, but from the records of wells in sec. 30, T. 29 N., R. 12 E., the Red or Stray sand, possibly containing oil, should be struck at a depth of about 1,050 feet, the Peru sand at about 1,150 to 1,200 feet, and the "Mississippi lime" at about 1,700 to 1,750 feet.

DEADMAN'S ANTICLINE.

The Deadman's anticline lies near the center of the N. ½ sec. 29 and the S. ½ sec. 20. As pointed out above, it is essentially a northward extension of the Coon Creek anticline. It does not promise to be important as a source of oil, being rather terrace-like in form, broad and flat, with only one (doubtful) closing contour and only one contour separating it from synclines on three sides. It is appropriate, moreover, to draw special attention here to the possibility, previously referred to, of the surface exaggeration of structure by slumping, not in blocks but as a whole bed, of a heavy sandstone like the Cheshewalla on the 60 feet or so of shale underlying it. The valleys of Coon Creek and its tributaries adjoin the three sides of the anticline corresponding to the synclines and expose the shale in steep faces. These steep shale slopes afford conditions unusually favorable for slumping and have produced all around this valley effects that may be very misleading as to the structure of the deeper-lying beds. The most conspicuous of these effects is the tilting of large masses of sandstone along the edges of the ridges in some places to or even beyond a vertical position, with a strike approximately at right angles to the elongation of the ridges. When followed along their strikes up the ridge these masses of sandstone are found to flatten rapidly till they merge into the unbroken flat bed at the top of the ridge. The condition is undoubtedly one of surface slumping, though it may be related to minor deeper lines of faulting or to lines of stress resulting from the larger folding of the beds. The same observation has been made and the same conclusion reached by other members of the Geological Survey working in this territory, but the disturbance is here so strongly developed as to deserve special mention. One of the most striking examples of it is afforded by Deadman's Rock, a nearly vertical ridge of the Cheshewalla sandstone, near the center of the south edge of sec. 20, north of the M ranch, on the northeast flank of this anticline. The only recorded development work on the Deadman's anticline is a dry hole shown on the location map of the Bureau of Mines as in the southeast corner of the NW. ¼ sec. 29. No further record of this hole is available. Its position is in the bottom of the saddle between the Coon Creek and Deadman's anticlines, and it is therefore not a conclusive test, yet the indications it affords are not favorable. It would be best to postpone further tests here till the more favorable Prairie anticline, to the northwest, has been explored. The best position for a test on the Deadman's anticline would be in the NW. ¼ NE. ¼ NW. ¼ sec. 29.

JUNCTION DOME.

The Junction dome may be regarded as a domelike expansion on the terrace-like northwestern extension of the axis of the Coon Creek anticline. It lies in the center of the W. ½ sec. 30. The dome does not appear very promising, on account of the gentleness of the slope of the west flank, with no pronounced flattening or reversal at the top to catch whatever oil might gather from the lower parts of the slope. It has been tested by a hole drilled almost on the summit of the dome, in about the NW. ¼ NE. ¼ SE. ¼ sec. 30, which penetrated 50 feet into the "Mississippi lime" and filled with salt water. This well can not be regarded as a conclusive test of the dome as a whole. A location on the west side of the crest would be better, and the entire dome can not be condemned until one or more tests are made along the brows of the flanking terraces.

BREAKNECK DOME AND PRAIRIE ANTICLINE.

From the Junction dome northward through the Prairie anticline the entire structure may be considered as a unit. Essentially it represents the eastward ridgelike summit of a slope extending up for 2½ to 3 miles from the eastern part of T. 29 N., R. 11 E. There are terrace-like expansions in this slope, but none of these is sharply enough defined by steep dips at its outer edge to make it appear especially favorable for the accumulation of oil. The Breakneck dome is a small summit represented by a single closed contour on this ridge in the SE. ¼ sec. 19, T. 29 N., R. 12 E. The reversal of dip is very slight here, and the terrace-like westward slope is very gentle and is partly interrupted by a synclinal pocket in the SE. ¼ sec. 24, T. 29 N., R. 11 E., which sends a tongue almost to the top of the anticlinal ridge a quarter of a mile north of the Breakneck dome. All these are factors that may reduce the chances of obtaining production from the dome. The only drilling known to have been done near this dome is a hole sunk on the top of the anticlinal ridge about halfway between the Junction and Breakneck domes. A show of oil was obtained in a sand, probably the Red or Stray sand, at 1,100 feet, and another in the Peru sand at 1,240 feet. The "Mississippi lime" was penetrated for 8 feet, from 1,780 to 1,788 feet, but no showing was reported. The "Mississippi lime" should have been penetrated for at least 200 feet. The location is less favorable than one to the northwest of the Breakneck dome or possibly than others fixed with special reference to the terrace features. A further test might be made on the Breakneck dome near the west edge of the NE. ¼ SW. ¼ SE. ¼ sec. 19. However, the writer believes that it would be better not to make any additional tests on this dome until the Prairie anticline, which is the most promising looking part of the general structural ridge, has been tried out. If this does not yield oil it is less likely to be found in other parts of the ridge.

The Prairie anticline is a broad, flat-topped fold striking about northwest, in the northeastern part of sec. 19 and the southwestern part of sec. 18, T. 29 N., R. 12 E. Beyond the summit the axis turns due west and pitches in that direction down the long slope which extends for almost 2 miles into T. 29 N., R. 11 E. The fold has a closure of 10 to 20 feet, with a doubtful small closed contour at about the south quarter corner of sec. 18. Although the eastward reversal of dip is slight and there is no sharp change of slope near the top to trap oil rising from the lower parts of the slope, the extensive west flank affords a large gathering ground for oil, part of which at least may be expected to have accumulated near the top of the anticline. No development work is known to have been done on this anticline. A favorable position for a test would be in the SW. ¼ SW. ¼ sec. 18, or possibly somewhat nearer the summit in the SW. ¼ SE. ¼ SW. ¼ of the same section. Immediately adjacent to the south quarter corner of sec. 18 gas would be expected. The Red or Stray sand should be found at a depth of about 1,100 feet, the Peru sand at about 1,250 feet, and the "Mississippi lime" at 1,750 to 1,800 feet.

OPOSSUM CREEK ANTICLINE.

From the Junction dome the main anticlinal axis continues southward with a slight curvature to the west and in the NW. ¼ sec. 31, T. 29 N., R. 12 E., turns west through the tonguelike Opossum Creek anticline, which crosses the township line about a third of a mile south of the northwest corner of sec. 31 and extends for at least half a mile into sec. 36, T. 29 N., R. 11 E. There is very little eastward reversal of dip and but one closed contour on this fold, which therefore has more the character of a terrace than of an anticline. Synclines south and northwest of it limit the gathering ground for oil, which is restricted to the west and west-northwest slope. The gentleness of this slope and the absence of any pronounced flattening at the top are further unfavorable features. No development work is known to have been done on this fold. A good position for a test would be just west of the summit in the NW. ¼ SE. ¼ NE. ¼ sec. 36, T. 29 N., R. 11 E.

RAMSEY ANTICLINE.

The Ramsey anticline is probably the most important structural feature in T. 29 N., R. 12 E. Its axis lies just east of the township line in Washington County, strikes almost due north, and extends with a northward pitch to a point opposite the northeast corner of sec. 28. The west flank extends at its widest part about three-fourths of a mile into T. 29 N., R. 12 E., but narrows toward the nose in the northern part of sec. 28. Oil is obtained all along this fold across the line in Washington County, and there is every reason for assuming that the productive area could be extended into T. 29 N., R. 12 E. The Indian office in Pawhuska has a record that two wells were drilled in the NE. ¼ sec. 33, T. 29 N., R. 12 E., in 1904 and 1905, but no further information about these wells is available. The most favorable location for beginning developments would be along the Osage-Cherokee line in the small sector of sec. 34 included in T. 29 N., R. 12 E., especially in the SW. ¼ NW. ¼ SW. ¼ sec. 34 and westward into sec. 33, T. 29 N., R. 12 E. As oil is obtained also farther down the nose to the north, just across the line in sec. 27 in Washington County, it is likewise to be expected in the small strip of that section in T. 29 N., R. 12 E., and in the eastern part of sec. 28. Most of the oil produced in the adjacent part of Washington County seems to come from a sand lying about 750 to 820 feet below the surface and overlain by 20 to 30 feet of lime "cap rock," in some places with 15 feet or so of shale intervening. In the record of one well drilled to the "Mississippi lime" the following beds are recorded:

	Feet.
Lime showing oil (Peru?)	1,175–1,185
"Oswego lime"	1,300–1,334
"Mississippi lime"	1,650–1,782

The Gap sandstone, which forms the surface of the Ramsey anticline in T. 29 N., R. 12 E., lies about 120 feet below the Cheshewalla sandstone. (See the standard section, fig. 46, p. 330, and Pl. XLIX.) The beds on which the different wells in the adjacent parts of Washington County started are not known. The depths just given to the productive beds in these wells do not show any consistent relation to the standard section, the "Oswego lime" being at the same depth below the surface here as below the Cheshewalla sandstone in the standard section but the "Mississippi lime" and the Peru sand being shallower. Possibly the sand at 750 to 820 feet is the Red or Stray sand, though it appears to be shallower. The nearest estimate that can be made of the depth to the different beds in the Ramsey anticline in T. 29 N., R. 12 E., is as follows: First productive sand (Red or Stray sand?), around 800 feet; Peru sand, 1,000 to 1,200 feet (?); "Mississippi lime," around 1,600 feet.

MERIDIAN TERRACE.

The Meridian terrace is a tonguelike terrace whose axis starts about one-fifth mile south of the northwest corner of sec. 15, T. 29 N., R. 12 E., runs west about half a mile, and then bends off to the southwest. A north-south anticlinal ridge of which this would be a lateral branch may be just east of the township line. An unofficial record shows a series of oil wells near the township line in the E. ½ NE. ¼ sec. 16, T. 29 N., R. 12 E., but there is no other record of these wells. If they actually exist their location is not really unfavorable with respect to the structure, especially if there is a north-south anticlinal ridge to the east of the township. Production there would encourage further exploration along the terrace to the west and southwest. Perhaps the most favorable location for a test is the point where a steep westerly dip is followed by a pronounced flattening[1] in the SE. ¼ NE. ¼ NW. ¼ sec. 16. A test might also be made at the top of the nose in the SE. ¼ NW. ¼ NE. ¼ sec. 16.

DOME WEST OF MERIDIAN TERRACE.

The small dome faulted on the east side which is shown on the map as occurring in the SE. ¼ sec. 18 and the SW. ¼ sec. 17, T. 29 N., R. 12 E., may be regarded as lying on an extension of the axis of the Meridian terrace. Its position just off the northeast flank of the Prairie anticline, from which it is partly separated by a small fault, is not very favorable. There is an unofficial record of a dry hole on the extreme northeast corner of this dome, just west of the fault in the northwest corner of the SW. ¼ sec. 17, T. 29 N., R. 12 E., but nothing further is known about it. A test might be made, as on the Meridian terrace, at the place where the terrace-like westward nose drops off more steeply, in the NE. ¼ NW. ¼ SE. ¼ sec. 18, but it would be best to await developments on the Prairie anticline, which, if successful, might be extended in this direction. Directly east of the hole in the SW. ¼ sec. 17, just mentioned, the same unofficial record shows two more dry holes, one of which when seen in the field was slowly flowing oil and therefore evidently yielded a showing. The location of these holes is not very favorable, as they appear to be rather too far north

[1] U. S. Geol. Survey Bull. 686-F, p. 58, 1918.

of the extension of the axis of the Meridian terrace, and on that side the gathering ground for oil is very small. The position of three wells, of which records are available, in the SE. ¼ sec. 17, T. 29 N., R. 12 E., is more favorable. The exact form of the extension here of the Meridian terrace is not known, but these wells are evidently all approximately near the top or a slight distance down on the flank of that terrace. Two of these wells record oil; one of them had an initial daily production of 5 barrels, but the yield of the other well was not given. The oil was obtained apparently from the Red or Stray sand, and the result offers some encouragement for further developments along this axis. If oil is found in the shallow sand drilling should be continued to the "Mississippi lime." In wells drilled in the bottom of Coon Creek valley where it crosses this terrace the "Mississippi lime" should lie at a depth of about 1,600 feet, the dry hole in the group of three having entered it at 1,607 feet. Wells on the ridges should enter it at a depth 100 to 150 feet greater.

T. 20 N., R. 10 E.

By Marcus I. Goldman.

INTRODUCTION.

The area described in this report is that part of T. 20 N., R. 10 E., which lies in Osage County. (See fig. 1.) The area was mapped in July and August, 1918, in two portions, as shown on the key map on Plate L. One portion was covered by Kirtley F. Mather, assisted by Harold C. Wire, instrument man. Edmund M. Spieker, W. G. Argabrite, and the writer cooperated on the geology of the other portion, in which most of the instrument work was done by Milton G. Gulley, with some help from E. Russell Bickel and Mary Ware Goldman. The description of surface features in the area covered by Mr. Mather was prepared by him.

In general, the area is one of thick series of sandstones with strong relief and a heavy cover of timber. Large parts of it, however, are so deeply buried under wind-blown sand that rock outcrops are more or less completely concealed and the topography assumes a much more rounded character; but even these parts are, to a large extent, covered with timber. On the structure map (Pl. L) the areas in which the mantle of sand was so heavy that the structure could not be determined are indicated by shading.

Over much of the area the structure was difficult to work out, on account of the lack of persistence of the beds followed. They were parts of thick series of sandstones and were brought out as benches only locally by the weathering back of softer overlying sandstone or thin lenticular beds of shale, so that they could be followed over only short distances and even there with some uncertainty. It is believed, however, that the general character of the structure is correctly represented, even if the portrayal is not exact in all details.

STRATIGRAPHY.

EXPOSED ROCKS.

The beds exposed in this area and the average distances between them are represented in the diagrammatic section (fig. 49). The most readily identifiable beds, which occur in the lower part of the section, are the Dewey limestone, Avant limestone, and *Fusulina*-bearing sandstone.

Dewey limestone.—The Dewey limestone, to which the position of all the other beds is referred, crops out in only a small area along the southeast edge of the township. It was identified by K. F. Mather, who was familiar with its occurrence in adjacent areas. As the exposure is poor and meager within this area it will be best to consult, for a more detailed description, the text describing T. 20 N., R. 11 E.,[1] directly adjacent. The lower half appears as a blue-gray fine-grained fossiliferous limestone; the upper half as a limestone that is more or less sandy or has a conglomeratic or brecciated structure. The total thickness is probably about 10 feet.

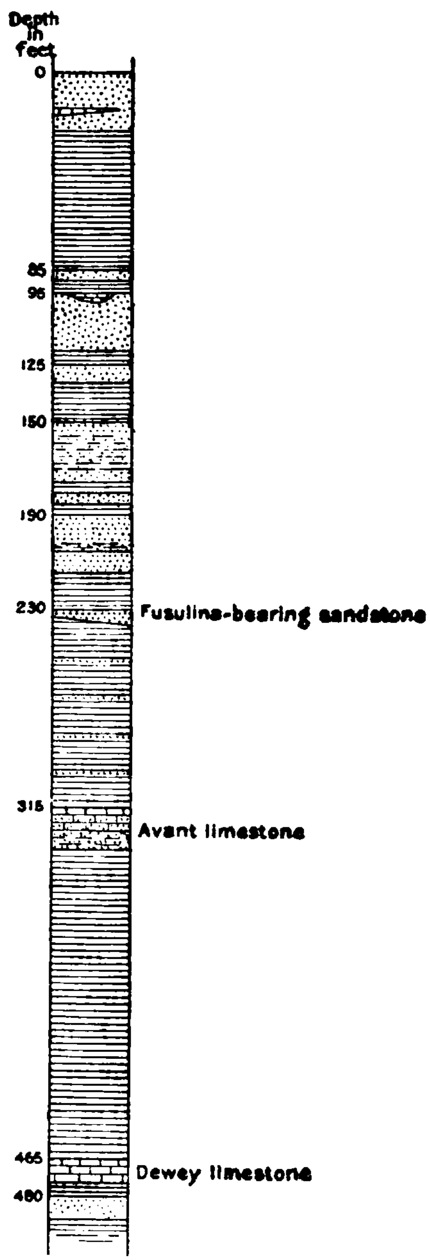


FIGURE 49.—Stratigraphic section showing rocks exposed in T. 20 N., R. 10 E.

Avant limestone.—The slope separating the Dewey limestone from the Avant limestone, which was also identified by K. F. Mather, is generally covered by soil and vegetation, a fact which in itself indicates the predominance of shale. No sandstone or limestone was noted in this interval. The Avant, though distinguished as a limestone, is really a variable and irregular mass of limestone and sandstone about 13 to 18 feet thick. Its most evident characteristic is the dark-brown, rusty color to which it weathers. This color penetrates more or less the interior of all the sandy portions and some of the more sandy limestone, but the pure limestone is light blue-gray on a freshly broken surface. Fossil shells are few and scattered. At the base is a massive bed, generally 10 to 15 feet thick. The upper 3 feet of this bed is a fairly pure ocherous limestone that grades into the sandy limestone or sandstone below. Above this basal bed are frequently found poorly exposed fragments of a compact, pure limestone which weathers to a creamy color and occupies a zone apparently about 3 feet thick. The top of this bed is taken at the

[1] Lloyd, E. R., and Mather, K. F., U. S. Geol. Survey Bull. 686-J, 1919.

top of the Avant limestone in this township. Above that there is in places 10 feet or so of a sandy bed similar to that at the bottom. The principal occurrence of the Avant limestone is in a strip 1¼ to 1½ miles wide along the southeast edge of the township, running south about 3½ miles from the northern part of secs. 13 and 14. It reappears, however, in small exposures in the southwestern part of the area, in the bottoms of the branch valleys at the edge of the flood plain of Arkansas River. In T. 20 N., R. 11 E., where opportunities for measuring intervals from the Avant to beds above and below it were more favorable, E. R. Lloyd and K. F. Mather reached the conclusion that the position of the Avant in the section is rather variable. In T. 20 N., R. 10 E., the interval to a *Fusulina*-bearing sandstone above it was found to range from about 86 feet in the southeastern part of the township to 60 feet or so in the southwest. The interval between this *Fusulina*-bearing sandstone and the Dewey limestone was found by Mather to be very constant. In T. 20 N., R. 10 E., therefore, the *Fusulina*-bearing sandstone was taken as the reference bed, to which, as far as possible, all elevations were reduced. The interval between the Avant limestone and the *Fusulina*-bearing sandstone is occupied mainly by shale but also contains beds of sandstone, some of them locally rather thick, but as none of these sandstones were used in working out the structure of the area they are not considered here.

Fusulina-bearing sandstone.—The *Fusulina*-bearing sandstone is a hard, platy bed, 3 to 5 feet thick, lying in the midst of shale. It is usually characterized by more or less abundant external molds of *Fusulina;* here and there these give way to shells of mollusks or brachiopods, and in some places no fossils are found, but this last condition is only local and where it occurs the bed can generally be recognized by its isolated position in the shale series and its relation to the heavy sandstone above it, or it can be traced to a point where *Fusulina* will be found in it. Five feet above the *Fusulina*-bearing sandstone there is in many places a sandstone of the same general character though without the *Fusulina* casts, and, where the lower bed does not carry them either, the two may be hard to distinguish.

Beds above Fusulina-bearing sandstone.—The series of beds above the *Fusulina*-bearing sandstone is highly variable and could be represented in the diagrammatic section (fig. 49) only in a general and somewhat arbitrary way. As a whole it may be said to consist of a thick succession of massive, generally soft sandstones. In the northeastern part of the area there are interbedded layers of shale, some of which are definite and persistent, but in the western and southwestern parts these shales become fewer and less persistent, the thinner sandstone lenses uniting to form heavy, massive sandstones, 30 feet or more thick, which along Arkansas River appear in precipitous walls about 250 feet high. There are some definite beds of shale in the series in the southwestern part of the area, but in many places the benches in the series are probably due rather to overlying, softer sandstones or sandy shales, which have weathered out. The same is true of many of the benches in the northeastern part of the area. As a consequence, no attempt has been made to correlate beds across areas through which they could not actually be traced more or less continuously. The highest bed observed in the northeastern part of the area was a sandstone about 380 feet above the Dewey limestone. The remainder of the section occurs in the western part of the area. In the northwestern part of the area, according to K. F. Mather, there are almost no shales in the section. A well-defined bench of sandstone about 315 feet above the Dewey limestone appeared to be the most constant and best-defined bed in the northeastern part of the area. Red shales are fairly common in the 60 feet above this sandstone, and some were also observed in various parts of the series in the area to the southwest. In the southwestern part of the area most of the elevations used in mapping (except those on a heavy bed of sandstone which forms a well-defined rim on the highest ridges, about 465 feet above the Dewey limestone) are referred directly to the *Fusulina*-bearing sandstone, which can be traced along the lower parts of most of the valleys. The rim-forming sandstone about 465 feet above the Dewey limestone can be identified over most of its outcrop by a dark blackish-brown limestone, resembling the Avant, in some places full of shells, especially of *Productus*, which occurs about 15 feet below the top of the sandstone. In the northwestern part of the area K. F. Mather recorded at 15 feet above what appears to be, from its position, the equivalent of the top of this high sandstone, "a thin sandstone * * * which contains abundant fossils, the majority of which are pelecypods and brachiopods."

UNEXPOSED ROCKS.

The records of only two wells in this area are available, and only one of these is at all complete. The important beds encountered are given in the following table:

Principal beds penetrated in well in sec. 13, T. 20 N., R. 10 E.

	Feet.
Lime [undoubtedly the Dewey limestone]	140– 153
Big lime	1,280–1,297
"Oswego lime"	1,370–1,415
Bartlesville sand	1,844–2,002
Tucker sand; little gas at 2,031 feet	2,028–2,045
Burgess sand	2,094–2,101
"Mississippi lime"	2,101–2,105

STRUCTURE.

In that part of T. 20 N., R. 10 E., which is covered by this report there are no closed anticlinal folds such as have been found to be favorable for the accumulation of oil and gas elsewhere in the Osage Reservation, and even the most pronounced of the folds which are present are not of a type to encourage a hope that they will prove to be underlain by great accumulations of either oil or gas. However, some parts of the folds are unquestionably better adapted to bring about such accumulations than others, and these moderately favorable areas should be the first to receive the attention of the "wildcatter." The possible presence of lenses of open-pored sandstone that can not be recognized in advance of boring may determine the presence of important oil pools, even where the surface structure is unfavorable.

The most prominent structural feature in the area is an anticlinal nose whose axis runs approximately east through the eastern part of sec. 26, a little south of the center of sec. 25, and into T. 20 N., R. 11 E., where the fold is much better developed and more prominent than it is in T. 20 N., R. 10 E. At least three wells have been drilled on that part of the fold which lies in T. 20 N., R. 10 E., without encountering oil in commercial quantity, but as no records are available it is not possible to state whether or not they were drilled to adequate depths and constitute fair tests of the possibilities of the fold, or whether they encountered showings of oil that would be sufficient to justify further drilling. One of these wells, a little northwest of the center of sec. 36, low on the flank of the fold, was producing gas at the time of the field examination. A second well, a little more than 1,000 feet east of the first, is a dry hole. Neither of these tests is well located with respect to the anticlinal folding, and the fact that one is a producing gas well is more surprising than the failure to encounter commercial quantities of oil. A third test, in the SE. ¼ SE. ¼ NE. ¼ sec. 25, is much better located with regard to the structure, as it is but 500 feet north of the axis of the fold, and if it was drilled into the "Mississippi lime" without finding good "shows" of oil or gas it indicates that the probabilities of obtaining good yields from the part of the fold which lies in T. 20 N., R. 10 E., are very poor. However, in the absence of definite information, this test can not be said to condemn the fold, and further testing in sec. 25, southeast, northwest, or west of this dry hole, appears justifiable.

In sec. 28 there is a terrace-like flat on which occurs a small dome-shaped bulge. This departure from the regional westerly dip should be tested. A good location for the test is a little northeast of the center of sec. 28.

In sec. 13 there is a rather pronounced anticlinal nose whose axis trends north-northwest across the section. This fold has already been tested by a hole that went to the "Mississippi lime" very near the crest without favorable results. However, another test a little farther north and to the west of the axis of this fold is probably justified, especially if good oil wells are developed in near-by territory.

In secs. 11 and 12 a gentle anticlinal fold pitching westward holds some promise of yielding oil or gas. In a region of more pronounced deformation it might well be overlooked, but in this district of low relief it stands out as more promising than the surrounding territory and is well worth a test. A good location for this test would be a little northwest of the center of sec. 11. Another location, perhaps less favorable, is a little west of the center of the SE. ¼ sec. 11.

A broad, flat terrace in sec. 2 presents structural conditions similar to those which at numerous localities in the Osage Reservation have been found to be associated with small accumulations of oil and gas. Where oil pools are developed near such terraces they are, as a rule, on the steep structural slopes either above or just below the broad flat. Accordingly, good places for testing this terrace would be just west of the east line of sec. 2, about midway between the east quarter corner and the northeast corner of the section. A second test might be made a little south of the center of the NE. ¼ sec. 3.

Terrace structure of some promise appears in the southwest corner of sec. 33 and the southeast corner of sec. 32, where a flattening of the westerly dip is succeeded by a marked steepening of the beds. A good location for a test would be just west of the east line of sec. 32, about midway between the east quarter corner and the southeast corner of the section.

A very considerable part of the township is concealed beneath wind-blown sand, and the structural conditions beneath this cover can only be guessed at. It seems probable that in sec. 34 there are either anticlines or synclines which depart radically from the general westerly dip of the regional structure. However, any anticline that may be concealed beneath the sand mantle is small in magnitude and consequently in probable importance.

T. 28 N., RS. 11 AND 12 E.

By Marcus I. Goldman and Heath M. Robinson.

INTRODUCTION.

The area considered in this report lies in the northeastern part of Osage County, Okla. (see fig. 1), 4 miles south of the Kansas line. It comprises all of T. 28 N., R. 11 E., and a little more than half of T. 28 N., R. 12 E., the remainder of which is in Washington County.

There are no towns within this area. The nearest town outside the area is Copan, in Washington County, about 5 miles to the east. The townships can also be conveniently reached from Caney, Kans., and Bartlesville, Okla. Farms and ranches are in large part confined to the creek valleys, the land elsewhere being used for cattle grazing, for which it is admirably adapted. The Osage County & Santa Fe Railway right of way passes through the area, following the valley of Mission Creek in the western part and the valley of Caney River in the northeastern part. The roads for vehicles are generally poor, owing to lack of attention, although the open character of the country and the absence of broad sandstone-covered areas make them much less rough and difficult to traverse than those in some other parts of the Osage Reservation.

The topography is marked by hills and ridges bordered by wide-bottomed valleys with steep sides. The greatest relief is at Sundown Hill, which overlooks the valley of Caney River. On the slopes of this hill is exposed the entire stratigraphic section represented in figure 50 below the top of the Iatan limestone. The strong relief, in conjunction with the wide view over the river valleys, permitted the establishment of a very full net of triangulation for horizontal and vertical control over the area. This control was facilitated by the fact that most of the country is open pasture, although there are two wooded ridges, one running southeastward from the summit of Sundown Hill and the other in sec. 33, T. 28 N., R. 12 E., and there is also some timber in the southwestern part of the area south of Mission Creek. The woods on the uplands are largely confined to land covered with sandy soil or areas where the outcropping rocks are for the most part sandstone.

Two large streams, Caney River and Mission Creek, flow through the townships, and from these streams and their larger branches water for drilling can be obtained throughout the year; but in the high areas between the streams water is scant.

The field work on the area covered by this report was done in the spring of 1918 by Marcus I. Goldman and Heath M. Robinson, assisted by the instrument work of Mary Ware Goldman and Louis Mosburg, respectively. The areas covered by the different men are shown on the key map on Plate LIV (p. 394). All elevations and locations were determined by plane table with telescopic alidade. All important elevations have a 2-foot limit of error, and the allowable limit of error on horizontal location is about 150 feet, but this limit was rarely approached. The senior author is responsible for the report but has incorporated suggestions from the junior author and facts for the area mapped by him.

The authors wish especially to acknowledge their obligation to Miss M. G. Wilmarth, secretary of the committee on geologic names of the United States Geological Survey, for her valuable aid in checking, correcting, and in various ways improving the stratigraphic tables and diagrams included in this report.

STRATIGRAPHY.

GENERAL SECTION.

The larger subdivisions into which the rocks of this region have been grouped and the names given to these subdivisions in adjacent parts of Oklahoma and Kansas are shown in the accompanying table. On Plate LI (p. 378), in columns 9, 10, and 11, the principal beds in these sections are shown graphically for comparison. As the area under consideration lies near the Kansas line, and as the Kansas section was the first to be studied and named and is therefore the standard for this part of the Mid-Continent field, it is considered worth while to reproduce the general section for Kansas as well as for Oklahoma. It will be found more difficult, however, to correlate sections in this area with the type section of Kansas than with those of northeastern Oklahoma. This is due to the fact that the Kansas section has been mostly studied in the central eastern part of the State, where the limestones are best developed. It is generally recognized that with few exceptions the limestones in the Kansas section thin or disappear toward the southern boundary of the State, while the shales between them thicken and become more sandy in that direction. As the shales and sandstones thicken more than the limestones thin, the total section in Oklahoma is thicker than in Kansas, as may be readily seen by comparison of column 11, Plate LI, with columns 7, 8, 9, and 10 on the same plate. The only two shales that are reported to thin toward the south are the Bandera shale[1] and the Vilas shale.[2]

[1] Ohern, D. W., Oklahoma Univ. Research Bull. 4, p. 20, 1910. Moore, R. C., and Haynes, W. P., Kansas Geol. Survey Bull. 3, p. 93, 1917.

[2] Moore, R. C., and Haynes, W. P., op. cit., p. 100.

		Avant limestone member. Relations to Plattsburg limestone of Kansas not determined.	
s Layton sand of ushing field.	Drum limestone.	Dewey limestone member.	
		Hogshooter limestone member.	
nate horizon of t sand" of Bar- region.			
nate horizon of t sand" of Bar- region.	Coffeyville formation.		
	Parsons formation.	Lenapah limestone member.	
ide sand of Bar-			
		Altamont limestone member.	Oologah limestone where Bandera shale is absent.
sand of Dewey-	Bandera shale.		
	Pawnee limestone.		
	Labette shale.		
s Oswego sand of	Fort Scott limestone.		
	Cherokee shale.		

In general, it appears that the limestones in the lower part of the section are more persistent than those in the upper part, so that there is better opportunity of correlating the beds encountered in the lower part of a well and therefore of knowing where to look for oil-producing beds. The correlation table and graphic diagrams included in this report are offered to help in carrying these correlations further. This work can be done to some extent by carefully recording the materials penetrated in wells and comparing the logs thus obtained. But to make correlations certain, fossils are generally necessary. Wherever larger fragments are obtained from a well, as in shooting it, they should be collected, carefully labeled as to locality and depth at which they were obtained, and if possible sent in to the Director of the United States Geological Survey, Washington, D. C., for study. By methods now being developed in this Survey it may be possible to make such studies and identifications even from the ordinary fine material obtained in drilling.

The correlation of individual beds is discussed somewhat more in detail in the following paragraphs:

EXPOSED ROCKS.

The rocks exposed in this area are shown in diagrammatic section in figure 50, and on a smaller scale but in their relation to overlying and underlying parts of the section in column 7, Plate LI (p. 378). The section lying above the Bowhan sandstone, as shown in column 7, is copied from the report in this series on T. 28 N., Rs. 9 and 10 E.; T. 29 N., R. 10 E.[3] In the following pages only the rocks exposed within the area of T. 28 N., Rs. 11 and 12 E., are discussed.

Top sandstone.—The massive sandstone shown at the top of the section is probably equivalent to the lower part or to the basal part of the "Chautauqua sandstone" of Adams.[4] (See table facing p. 360, column 1.) If it is the basal part of the "Chautauqua sandstone," it includes the Jonesburg sandstone, which occurs to the north, in T. 29 N., R. 11 E.[5]

Bowhan sandstone.—The Bowhan sandstone is named from Bowhan Point, in sec. 16, T. 28 N., R. 11 E. (see Pl. LIV), which is capped by this sandstone. This is the highest bed used in working out the structure of the area. It is thin and slabby and weathers to a cinnamon color. It forms the top of many ridges in the southwestern part of the area and can generally be recognized by its position at the top of a thick series of shales. It is one of the lower sandstones in the Lawrence shale of the Kansas section (see column 1 of table facing

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[3] U. S. Geol. Survey Bull. 686–F, p. 44, 1918.

[4] Kansas Univ. Geol. Survey, vol. 3, pp. 58, 59, 1898; vol. 9, p. 107, 1908 (cf. U. S. Geol. Survey Bull. 686–W, p. 330, 1920).

[5] U. S. Geol. Survey Bull. 686–W, pp. 329–330, 1920.

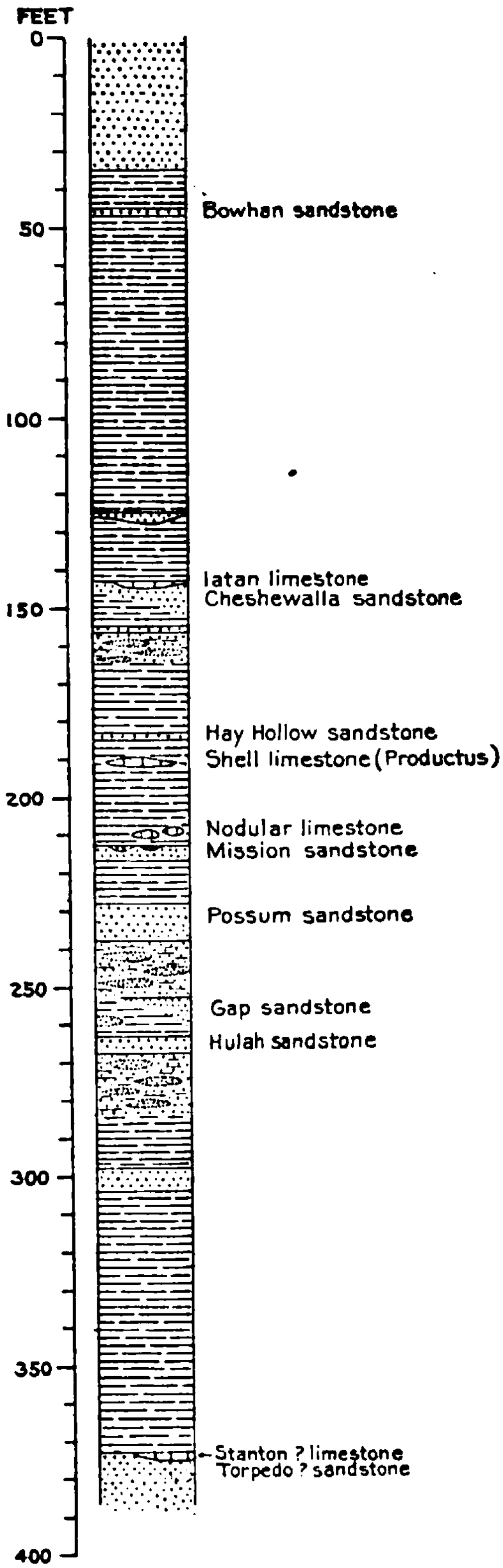

FIGURE 50.—Generalized graphic section of rocks exposed in T. 28 N., Rs. 11 and 12 E.

p. 360), probably the equivalent of the Jonesburg sandstone to the north, in T. 29 N., R. 11 E.,[6] unless the Jonesburg sandstone is the basal part of the massive sandstone at the top of the succession of beds in this township.

Iatan limestone.—What is believed to be the same as the Iatan limestone of Kansas has been traced into this area from T. 29 N., R. 11 E., and some of the reasons for believing it to be the Iatan limestone are given in the report on that township.[7] This conclusion is further confirmed by comparison of columns 7 and 11 in Plate LI. In both these sections the distance from the top of the Oread limestone to the top of the bed called the Iatan limestone is the same, 275 feet. The Iatan limestone is lenticular and reaches a maximum thickness of 8 feet. In most of this area it is made up chiefly of the shells of *Fusulina*, resembling grains of wheat. It is fairly constant in the northwestern part of the area on both sides of Caney River, where it averages about 2 feet in thickness, but is absent at many places to the east, south, and southwest at the horizon at which it should occur, tending to disappear altogether on the south side of Mission Creek. Where present to the east it is commonly brecciated, containing fragments of red and yellow limestone 1 inch to 2 inches or more in diameter. Where absent it is in places represented by impressions of fossils on the

[6] U. S. Geol. Survey Bull. 686–W, pp. 329–330, 1920.

[7] Idem, p. 331.

top of the underlying Cheshewalla sandstone. The most easterly exposure found was 5 feet below the summit of Sundown Hill, in the SE. ¼ sec. 18, T. 28 N., R. 12 E., where there are big slabs about 8 inches thick of impure brecciated yellow limestone. It is in many places overlain by 5 feet or so of sandstone and generally underlain by the Cheshewalla sandstone. It occurs about 100 feet below the Bowhan sandstone.

Cheshewalla sandstone.—The Cheshewalla sandstone is a massive sandstone usually 10 feet or more thick in the eastern part of this area but thinning to 3 feet toward the southwest edge. It lies immediately under the Iatan limestone. The top surface generally carries impressions of fossils, especially of *Fusulina*, by which it can be identified in the absence of the overlying limestone, as for instance in the southern part of the area of its outcrop.

Hay Hollow sandstone.—The Hay Hollow sandstone is named from its occurrence along the upper part of Hay Hollow in secs. 25 and 36, T. 28 N., R. 11 E. It is a slabby sandstone, generally about a foot or less in thickness, fine grained, compact, hard, and of a rather warm yellow color. At many places it contains peculiar winding, cylindrical sandstone casts half an inch in diameter, closely interwoven, which cover the surfaces of slabs. As it occurs about 40 feet below the top of the Cheshewalla sandstone, isolated in the midst of a thick series of shale, and weathering out in a well-defined line of large broken slabs, it is easily recognized. Care must be taken, however, not to confuse it with a somewhat similar hard, slabby bed which lies approximately 10 or 15 feet below the top of the Cheshewalla sandstone and likewise forms a conspicuous outcrop in the midst of shale around Sundown Hill and around the point west of the mouth of Hay Hollow. This higher bed is orange-colored rather than yellow and is generally rich in impressions of fossils, especially of bivalves, instead of the wormlike markings that are so common on the surface of the Hay Hollow sandstone.

Beds between Cheshewalla and Hay Hollow sandstones.—In the upper part of the succession of beds between the Hay Hollow and Cheshewalla sandstones, in the 15 feet or so below the Cheshewalla, there are a number of thin lenticular sandstones which in places merge with one another and with the Cheshewalla. The sandstone exposed around Sundown Hill, 10 to 15 feet below the top of the Cheshewalla, is the most persistent of these lenticular beds. Others are well defined for short distances and have been used locally in working out the structure, especially in the eastern part of T. 28 N., R. 11 E., south of Caney River. Below these lenticular sandstones, as far as the Hay Hollow sandstone, the section consists mostly of shale.

Mission sandstone.—The Mission sandstone is named from its prominent occurrence along Mission Creek, especially in secs. 13, 14, 23, 24, and 25, T. 28 N., R. 11 E. Just northwest of the center of sec. 23, T. 28 N., R. 11 E., it is conspicuous as the bed forming the surface of the prairie a few feet above the creek bottom north of the Gordon ranch. In T. 29 N., Rs. 11 and 12 E., it is part of a series of lenticular sandstones overlying the Possum sandstone.[9] In T. 28 N., Rs. 11 and 12 E., it is a very constant, conspicuous bed of hard sandstone, 2 to 4 feet thick, weathering in slabby blocks, prevailingly of a pinkish color, in places carrying fossil shells in the top part and forming the surface bed over a great part of the open country between Caney River and Mission Creek. This last-mentioned fact indicates that it is generally overlain by shale, hence the ease with which it is traced. In the southeastern part of the area, however, it becomes more or less lost in a series of soft, massive lenticular sandstones and appears in sec. 31, T. 28 N., R. 12 E., as part of a continuous massive bed 20 feet or more thick. The distance from the top of the Cheshewalla sandstone to the top of the Mission sandstone is generally about 70 feet, but perhaps decreases to 60 feet near the center of sec. 10, T. 28 N., R. 11 E.

Beds between Hay Hollow and Mission sandstones.—The section between the Hay Hollow and Mission sandstones consists almost entirely of shale. About 20 feet above the Mission sandstone is found locally a very lenticular slightly greenish limestone a few inches thick, consisting almost entirely of the thin, somewhat pearly looking shells of *Productus*, lightly bound together by a matrix of sandy clay. It could nowhere be traced any distance. One of the best exposures of it is on the south slope of a small point near the center of the north edge of the SW. ¼ SE. ¼ sec. 14, T. 28 N., R. 11 E.

The fossiliferous nodular limestone shown in figure 50 (p. 362) in the shale some 2 to 4 feet above the Mission sandstone was found only in the steep south bank of Caney River directly adjacent to the southwest corner of sec. 7, T. 28 N., R. 12 E., where the Mission sandstone locally develops into a more massive bed some 8 feet or more thick.

Not uncommonly there appear at the very top of the Mission sandstone, merging more or less with the sandstone, lenses from a fraction of an inch to a few inches thick of unfossiliferous limy substance, which weathers to a dark, blackish brown, and is therefore probably more or less sideritic and manganese bearing. This material is particularly conspicuous along the south side of Mission Creek in and adjacent to sec. 30, T. 28 N., R. 12 E.

Possum sandstone.—The Possum sandstone is of entirely the same character here as in T. 29 N., Rs. 11 and 12 E.[9] It is a prominent,

[9] U. S. Geol. Survey Bull. 686–W, p. 332, 1920.

persistent, thick, relatively soft massive sandstone, of the same general type as the Cheshewalla sandstone, though usually not so thick. It lies about 15 feet below the top of the Mission sandstone.

Hulah sandstone.—The Hulah sandstone is named from its good development at the top of the small ridge at the east edge of the town site of Hulah, on the unfinished Osage County & Santa Fe Railway, near the center of the SE. ¼ sec. 5, T. 28 N., R. 12 E. It is a hard bed that averages about 4 feet in thickness and usually weathers yellow or orange colored. The interval separating it from the top of the Mission sandstone ranges from 40 to 55 feet and averages about 50 feet. The position of this sandstone in the midst of shales in the eastern and northeastern parts of the area generally causes it to have a well-defined outcrop at or near the tops of ridges there. In the southeastern part of the area numerous lenticular sandstones above and below it make it more difficult to trace. In places it is rather fossiliferous—nowhere more so than at its type locality, just east of the town site of Hulah, where *Productus* is particularly abundant.

Beds between Possum and Hulah sandstones.—In the northeastern part of T. 28 N., R. 12 E., the section between the Possum and Hulah sandstones consists mainly of shale, with only a few lenticular sandstones, such as the Gap sandstone, which pinches out half a mile south of the northeast corner of the township. South and west of Caney River, however, this part of the section consists almost entirely of closely interbedded more or less lenticular sandstones and shales. As a consequence, south of Mission Creek, where this part of the section is mainly exposed, beds can be followed only locally in mapping the structure.

Torpedo (?) sandstone.—The sandstone to which the name Torpedo is here tentatively applied is believed to be the probable equivalent of the Torpedo sandstone described in another chapter of this bulletin.[10] It lies near the bottom of the section exposed in the townships, about 160 feet below the top of the Mission sandstone, and is the lowest bed used in mapping. On account of its prevalent position in the valley floor it is rarely well exposed. A good exposure, however, at the edge of Coon Creek in the SE. ¼ SW. ¼ sec. 9, T. 28 N., R. 12 E., shows 15 to 20 feet of rather soft massive sandstone of the general type of the massive Cheshewalla and Possum sandstones. It is believed that the heavy sandstone that forms the plateau on which stands the schoolhouse in the northwest corner of sec. 28, T. 28 N., R. 12 E., on the point between the valleys of Caney River and Mission Creek, is the same sandstone, and the correlation across Caney River has been based largely on that belief. Along the edge of the plateau there is an excellent cliff-like exposure showing

[10] U. S. Geol. Survey Bull. 686–H, p. 76, 1918.

about 15 to 20 feet of massive sandstone. The record of the well in the SW. ¼ sec. 9, T. 28 N., R. 12 E., which starts just above this (Torpedo?) sandstone, begins with a bed of sandstone 65 feet thick. In the northeast corner of the NW. ¼ NW. ¼ SE. ¼ sec. 9, T. 28 N., R. 12 E., along the edge of the valley of Coon Creek, the upper 5 feet or so of the sandstone was found to pass into a barren limestone and calcareous sandstone overlain by about 5 feet of sandstone, part of which is full of impressions of shells, among which *Pecten* and *Productus* were especially noted. A better-defined occurrence of limestone was found in the bed of Coon Creek adjacent to a road crossing near the west edge of the NW. ¼ SW. ¼ NW. ¼ sec. 16, T. 28 N., R. 12 E. Here there is exposed about 4 feet of very sandy limestone to very calcareous sandstone, ripple marked, full of crinoid stems, with *Productus* and other fossil shells. The relation to the Torpedo (?) sandstone could not be determined here, but the dip and general relations make it practically certain that this limestone is equivalent to the bed occurring in sec. 9 just described and lies at the top of the Torpedo (?) sandstone. As will be explained below, this is very probably the Stanton limestone.

Beds between the Hulah and Torpedo (?) sandstones.—The beds between the Hulah sandstone and the Torpedo (?) sandstone show the same variations as those between the Possum and the Hulah; that is, to the east and northeast they are mostly shale with only thin sandstone, while to the south and west of Caney River they are closely interbedded lenticular sandstones and shales, which can be followed only locally.

Possible correlations of the section between the Iatan limestone and the base of the Torpedo (?) sandstone.—As most of the limestones in this part of the Pennsylvanian series in Oklahoma grow thin or disappear toward the south and west, and the sandstones are very lenticular and not limited to definite horizons, any correlation, except as determined by actually tracing beds, is necessarily inconclusive. To a certain extent beds were traced continuously in preparing this series of geologic reports on the Osage Reservation. However, as the names in use in these reports and in others on northeastern Oklahoma were generally applied to thick series of beds, while the mapping of structure was based on single benches, and different geologists working in adjacent townships did not always use the same benches, the tracing is not entirely continuous. Some further evidence on correlation may be obtained by comparing the generalized section for T. 28 N., Rs. 11 and 12 E. (column 7, Pl. LI, p. 378) with the generalized sections for northeastern Oklahoma (columns 8 and 9, Pl. LI), as there is pretty close agreement in the total interval between the Oread limestone or probable equivalent of the Oread limestone and the top of the Fort Scott limestone or "Oswego lime" in these three sections.

The thick sandstone series exposed in the bluffs west of Bigheart [11] was named the Bigheart sandstone by Snider.[12] The name has, however, been restricted by the geologists of the United States Geological Survey to the basal massive sandstone of this series.[13] As thus defined it is mapped in secs. 1 and 2, T. 24 N., R. 10 E.[14] The top of the Revard sandstone as mapped in sec. 35, T. 25 N., R. 10 E.,[15] is apparently continuous with the top of the Bigheart sandstone as originally described by Snider. The series of sandstones called the Revard sandstone has been traced with sufficient continuity to T. 28 N., Rs. 11 and 12 E., to permit its approximate identification there. Apparently it tends to break up in this northeasterly direction into a number of thinner sandstones with considerable intervening shale, but its relations to the Iatan limestone and the Cheshewalla sandstone underlying the Iatan limestone indicate that the top of the Possum sandstone coincides approximately with the top of the Revard sandstone.

The correlation of the Torpedo(?) sandstone in this area is based on the following facts:

1. It lies in about the same position in the section shown in column 7, Plate LI (p. 378), as the top of the Wilson formation of Shannon and Trout (column 9). The Torpedo sandstone as defined in chapter H [16] of this bulletin lies at the top of the Wilson formation of Shannon and Trout.

2. In chapter H of this bulletin [16] 3 to 4 feet of crinoidal limestone, tentatively correlated with the Stanton limestone, is described as overlying the Torpedo sandstone. From 3 to 4 feet of crinoidal limestone was found at the top of the Torpedo(?) sandstone in T. 28 N., R. 12 E.

3. Ohern [17] states that the Stanton limestone passes into the Pawhuska quadrangle in the middle of T. 28 N. It was near that locality that the limestone overlying the Torpedo(?) sandstone was found. Besides, as the Torpedo(?) sandstone appears to be so nearly the lowest bed exposed in that vicinity, the Stanton limestone of Ohern is not likely to be any lower in the section.

4. Ohern [18] describes the Stanton limestone as very arenaceous near the Kansas-Oklahoma line. The limestone in the bed of Coon Creek in the NW. ¼ sec. 16, T. 28 N., R. 12 E., is very arenaceous.

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[11] See column 9, Pl. LI; also Oklahoma Geol. Survey Bull. 19, pt. 1, p. 89, 1915.
[12] Snider, L. C., Oklahoma Geol. Survey Bull. 7, p. 221, 1911.
[13] U. S. Geol. Survey Bull. 686–B, p. 8, 1918.
[14] U. S. Geol. Survey Bull. 686–D, pl. 5, p. 18, 1918.
[15] U. S. Geol. Survey Bull. 686–G, pl. 10, p. 60, 1918.
[16] U. S. Geol. Survey Bull. 686–H, p. 76, fig. 18, 1918.
[17] Oklahoma Univ. Research Bull. 4, p. 33, 1910.
[18] Idem, p. 34.

5. Green[19] describes a series of thick sandstones, associated with limestone probably equivalent to the Stanton limestone, in about the same position (cf. column 8, Pl. LI) as the Torpedo(?) sandstone in the section shown in column 7, Plate LI.

6. Like the sandstones in approximately the same position in the sections shown in columns 8 and 9, Plate LI, the Torpedo(?) sandstone in the section shown in column 7 is separated by an apparently persistent shaly series from rather massive sandy series above and below it.

If the Torpedo sandstone and the top of the Revard sandstone are correctly identified, then the Bigheart sandstone as defined by the geologists of the United States Geological Survey[20] must be represented by some of the sandstone in the lower part of the sandstone series above the Torpedo(?) sandstone and below the top of the Revard sandstone. But no one bed in this lenticular series appears preeminent enough in thickness or persistence to permit correlation with the Bigheart sandstone as above defined.

ROCKS NOT EXPOSED.

GENERAL RELATIONS.

The six well logs, two of them incomplete, that are shown on Plate LI (p. 378) are the only record of subsurface conditions available for this area. In figure 51 the locations of these wells are shown, with some of the most significant facts brought out by the logs. With the data obtained from these wells are shown curves representing the interval between the top of the "Oswego lime" and the top of the "Mississippi lime" as given by Berger.[21] As Berger's map is on a much smaller scale than this one, his curves could be transferred only approximately. In general, there is good agreement between his curves and the figures here given, the only pronounced disagreement being in reference to the well in the SW. ¼ sec. 9, T. 28 N., R. 12 E. In the log of this well the distance from the horizon of the Iatan limestone to the "Oswego lime" appears too small and that from the "Oswego lime" to the "Mississippi lime" appears too large, so that there was probably some mistake in reporting the depth of the "Oswego lime." In order to obtain the figures used here some reinterpretation of the logs was necessary, the name "Oswego lime" and other names apparently having been applied by the driller to the wrong bed, or no name having been given by the driller. A further interesting relationship brought out by the diagram (fig. 51) is a parallelism between the

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[19] Am. Assoc. Petr. Geologists Bull., vol. 2, p. 121, 1918.

[20] U. S. Geol. Survey Bull. 686–B, p. 3, 1918; Bull. 686–S, p. 240, 1919.

[21] Berger, W. R., The relation of the Fort Scott formation to the Boone chert in southeastern Kansas and northeastern Oklahoma: Jour. Geology, vol. 26, pp. 618–621, 1918.

interval from the Iatan limestone (a surface bed) to the "Mississippi lime" and the interval from the "Oswego lime" to the "Mississippi lime." In the northwestern part of the area the two intervals seem to vary by about the same amounts and in the same direction, which shows that the Iatan limestone and the "Oswego lime" are approximately parallel there. But southeast of Berger's 450-foot curve the interval between the Iatan limestone and the "Mississippi lime" increases abruptly but, so far as can be judged from the meager data available, in a direction parallel to that along

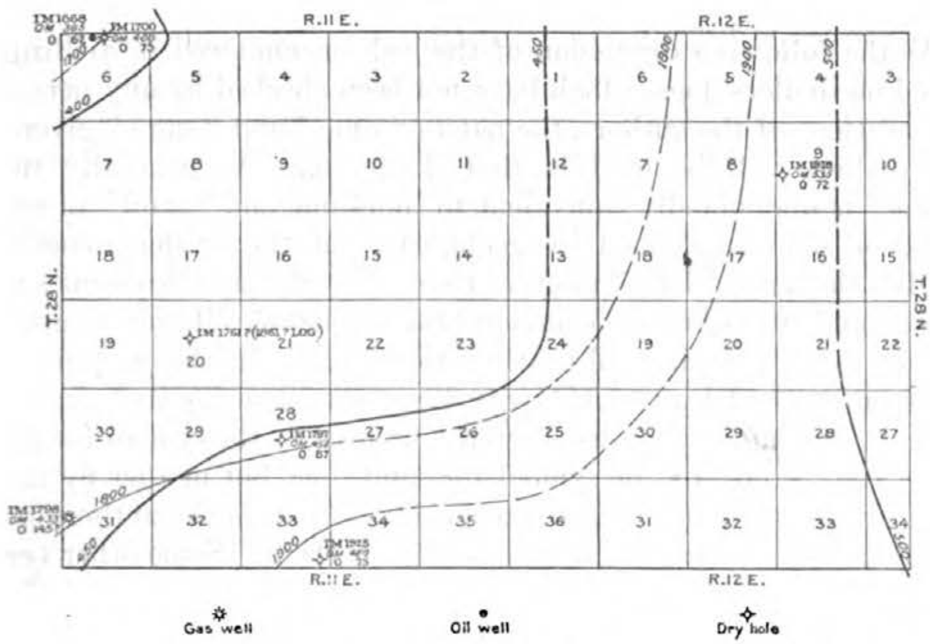

FIGURE 51.—Map showing the approximate intervals, in feet, between the base of the Iatan limestone and the top of the "Mississippi lime" (numbers preceded by "IM") and between the top of the "Oswego lime" and the top of the "Mississippi lime" (numbers preceded by "OM") in T. 28 N., Rs. 11 and 12 E. The light curves connect points at which the Iatan–"Mississippi" interval is approximately the same; the heavy curves (copied from Berger, W. R., Jour. Geology, vol. 26, p. 619, 1918) connect points at which the "Oswego"–"Mississippi" interval is approximately the same. Numbers preceded by "O" represent thickness of "Oswego lime."

which the interval between the "Oswego lime" and the "Mississippi lime" increases.[22] This appears to indicate that the same subsiding basin as that in which the beds between the "Oswego lime" (Fort Scott limestone) and the "Mississippi lime" (Boone limestone) were deposited existed and continued to subside southeast of the position of Berger's 450-foot curve during at least part of the time between the deposition of the "Oswego lime" and the deposition of the Iatan limestone. This is of practical importance, as it gives a rough means of determining, so far as the scanty data permit, the probable depth

[22] The northward extension of the 1,800-foot curve for the interval between the Iatan limestone and the top of the "Mississippi lime" is based on the logs of two wells in sec. 30, T. 29 N., R. 12 E.

to which any well in the area will have to be drilled to reach the "Mississippi lime." The outcrop and structure map (Pl. LIV, p. 394) shows the nearest surface bed, and the generalized section of exposed rocks (fig. 50, p. 362) shows the distance from that bed to the Iatan limestone. By combining these quantities with the intervals between the Iatan limestone and the "Mississippi lime" given on figure 51 the distance from the surface to the "Mississippi lime" can be calculated within about 50 feet or less.

PRINCIPAL BEDS ABOVE THE "MISSISSIPPI LIME" NOTED IN DRILLING.

As the following discussion of the beds encountered in drilling is based on drillers' logs, which have not been checked by any personal observations of the authors, the names "lime" and "sand" given by the drillers will be used in that discussion. As generally used, "lime" is undoubtedly equivalent to limestone and "sand" to sandstone or sand as defined by geologists, but the driller sometimes applies the name "lime" to other hard beds such as calcareous sandstones, and it has become common practice among oil men to use the word "sand" for any oil-bearing formation. In the graphic sections on Plates LI and LIII (pp. 378, 382), showing rocks encountered in drilling, "lime" has been represented by the symbol for limestone and "sand" by the symbol for sandstone, but neither by using these symbols nor by using the terms in the text do the authors commit themselves to any definite meaning for them. Some other terms used by the driller have been translated into the common geologic symbols to which they were believed to be most nearly equivalent—for example, "slate" is represented as shale, and in column 10, Plate LIII, "flint granite" is represented as flint.

For convenience in comparison the graphic well logs (columns 1 to 6, Pl. LI) are brought to a horizontal line at the approximate horizon of the base of the Iatan limestone. (See also fig. 51, p. 369.)

The first bed to be noted, numbered 1 in column 7, is a water sand which in the southwestern part of the area lies about 535 feet below the Iatan limestone. In the well in sec. 9, T. 28 N., R. 12 E. (column 6, Pl. LI), probably the same bed is recorded at about 519 feet below the Iatan limestone. The thickness recorded in different logs is variable. In the wells represented in columns 4 and 5 it probably includes a bed of limestone.

Another water sand (No. 2) lies a short distance lower in the section, at 640 to 670 feet below the Iatan limestone. The thickness of this sand is also highly variable. At the southwest edge of the township, in the NW. ¼ sec. 31, beds 1 and 2 apparently converge and reach their greatest combined thickness of 180 feet, with only 15 feet of blue shale separating them. There they are probably the same as the 60 feet or so of water sand with a show of oil and gas encountered at a depth of about 620 feet in a well in the SE. ¼ sec. 24, T. 27 N., R. 10 E., of which the diagrammatic log is shown in the report on that township.[23] A sand probably equivalent to the upper of these two and yielding gas and water was also encountered in T. 29 N., Rs. 11 and 12 E., about 550 feet below the Iatan limestone.[24] In Tps. 28 and 29 N., R. 10 E., the gas sand numbered 4 in the compiled section 6, Plate IX of Bulletin 686–F, is probably equivalent to the lower of these two sands or to the two converged into one. In the generalized section in the report on T. 27 N., R. 11 E.,[25] the second sandstone above the Little lime, about 670 feet below the top of the Cheshewalla sandstone, is in the position of the lower of the two sandstones under discussion, though it may represent the two combined. There is no indication that in that township it carried water, oil, or gas. In T. 28 N., Rs. 11 and 12 E., no gas or oil is reported from this sand, and the water is apparently generally salt. To sum up, the sands at the approximate horizon of these two gave a show of oil and gas in T. 27 N., R. 10 E., some gas in T. 29 N., Rs. 11 and 12 E., and a trace to 3,000,000 cubic feet of gas a day in Tps. 28 and 29 N., R. 10 E., though more generally they carry only salt water. Both of them, but especially the lower one, at about 650 feet below the horizon of the Iatan limestone, should be looked for in drilling in T. 28 N., Rs. 11 and 12 E., as there is some possibility of their yielding gas or small quantities of oil.

A comparison of columns 4, 5, and 7 with columns 8 and 9, Plate LI, makes it evident that these sandstones are in about the same positions as the Avant and Dewey limestones. It seems probable, therefore, that the limestone in the lower part of bed 1 is the equivalent of the Avant limestone, and that one or both of those directly above and directly below bed 2 represent the Dewey limestone.

About halfway between these sands and the Little lime, about 800 feet below the Iatan limestone, is a sand numbered 3, in column 7, Plate LI (p. 378), which in the log of the well near the west quarter corner of sec. 31, T. 28 N., R. 11 E., is reported to be 18 feet thick and to have yielded a show of oil. According to that log it lies nearly 250 feet above the top of the Little lime, a position which makes it about equivalent to a thin sand with a show of oil recorded 280 feet above the Little lime in the SE. ¼ sec. 24, T. 27 N., R. 10 E.[26] In T. 27 N., R. 11 E., a sand with salt water and a show of oil,[27]

[23] U. S. Geol. Survey Bull. 686–V, pl. 47, p. 306, 1919.
[24] U. S. Geol. Survey Bull. 686–W, fig. 47, p. 334, 1920.
[25] U. S. Geol. Survey Bull. 686–T, pl. 42, p. 262, 1919.
[26] U. S. Geol. Survey Bull. 686–V, pl. 47, p. 306, 1919.
[27] U. S. Geol. Survey Bull. 686–T, pl. 42, p. 262, 1919.

which lies about 250 feet above the Little lime, may be taken as the equivalent of bed 3 in T. 28 N., Rs. 11 and 12 E.

A sand which has been tentatively correlated with this on Plate LI is recorded in the logs of three other wells in T. 28 N., Rs. 11 and 12 E., but is not reported to have yielded indications of oil or gas in any of them. The distance of the bed above the Little lime seems to decrease toward the northeast. At 40 feet above this sand in the well in the NW. ¼ sec. 31, T. 28 N., R. 11 E., occurs a bed of limestone 20 feet thick which on Plate LI has been correlated with limestones in similar positions in other wells in the area. The position and persistence of this limestone favor the belief that it is the equivalent of the Hogshooter limestone shown in columns 8, 9, and 10, Plate LI. If that is so, the sand below it (No. 3, column 7, Pl. LI) appears to be approximately equivalent to the lower of the sands called the Layton sand in column 8, and said to be the equivalent of the 700-foot sand of the Bartlesville region, or to the 225-foot sand of the Bartlesville region shown in column 9. Sand No. 2, column 7, above this limestone, is then about equivalent to the upper of the two sands called the Layton sand in column 8, or to the Layton sand of the Cushing field, column 9. Definite correlation on the basis of sections so generalized is out of the question, but even this rough correlation brings out the fact that there are in this part of the stratigraphic section, between 530 and 825 feet below the Iatan limestone, a number of sands productive in this general region which should therefore be carefully watched for in drilling. In the immediate neighborhood of these townships the lowest of these sands appears the most likely to produce oil.

The bed named the Little lime in the graphic logs of wells in these townships on Plate LI was not so named by the drillers in any of these logs, but from its thickness (20 to 52 feet) and its distance above the top of the Big lime (120 to 174 feet) it is evidently the equivalent of the Little lime, as shown in the other graphic sections on Plate LI and in the logs of wells in T. 27 N., Rs. 10 and 11 E.[28] In T. 27 N., R. 10 E., the distance above the top of the Big lime ranges from 85 feet in the extreme southern part of the township to probably 185 feet in the northern part, though the Little lime is generally not identified in the logs in the northern part of that township. In T. 27 N., R. 11 E., the distance above the Big lime is about 120 to 180 feet, in general also increasing toward the north. To the north and west, in T. 28 N., R. 10 E., and T. 29 N., Rs. 10, 11, and 12 E., this bed has not been recognized. It gave a show of oil or gas in a few wells in T. 27 N., Rs. 10 and 11 E., but none in T. 28 N., Rs. 11 and 12 E. It should, however, be watched for in drilling in

[28] U. S. Geol. Survey Bull. 686–T, pl. 42, p. 262, 1919; Bull. 686–V, pl. 47, p. 306, 1919.

T. 28 N., Rs. 11 and 12 E., where it is the first prominent lime encountered and lies about 1,000 to 1,075 feet below the horizon of the Iatan limestone.

As mentioned above (p. 361), the limestones in the lower part of the stratigraphic section in northeastern Oklahoma appear to be continuous over a larger part of the area than those in the upper part of the section. The Little lime is the highest of the beds encountered in drilling in these townships that can be somewhat accurately correlated with the beds exposed at the surface. A comparison of the diagrammatic sections, columns 7, 8, and 9, Plate LI (p. 378), shows that the top of the Lenapah limestone lies exactly the same distance above the base of the "Oswego lime" (440 feet) in columns 7 and 9, and 430 feet above it in column 8. Ohern[29] has recently expressed the opinion that the Checkerboard lime, generally considered the same as the Little lime, corresponds not to the Lenapah limestone but to one that lies 70 feet above the outcrop of the Lenapah limestone at Nowata. However, his correlation seems to apply more to the southeastern part of Osage County, as he bases his conclusion on the fact that the Lenapah limestone does not extend southward beyond Nowata. As T. 28 N., Rs. 11 and 12 E., lie northeast of Nowata, this consideration would not bear on correlation in this direction. In the absence of detailed studies the correlation can be only approximate at best, especially as some of the logs of wells in T. 28 N., Rs. 11 and 12 E., show more than one bed of limestone included in or adjacent to the one tentatively called the Little lime in the diagrammatic sections on Plate LI. In any case, beds of lime approximately corresponding to the Lenapah limestone are to be looked for through an interval of 30 to 75 feet at about 1,000 to 1,075 feet below the horizon of the Iatan limestone.

The interval between the Little lime and the next bed generally recorded below it, the Big lime, is usually occupied by shales, locally with a thin lime or sand. If the Little lime is approximately equivalent to the Lenapah limestone, the position of these beds below that limestone makes them approximately equivalent to the Nowata shales of Ohern and other Oklahoma geologists. (See table facing p. 360, and Pl. LI, columns 9, 10, and 11.) In the log of the well in the southeast corner of sec. 33, however, the Little lime is reported to be underlain by 75 feet of nearly continuous sandstone. In certain areas the sandstone recorded in this (No. 5) interval is an important reservoir for oil, but it is lenticular and irregular in its distribution and character. The drillers in these townships and in adjacent parts of Oklahoma and Kansas have often called this the Peru sand. As in the case of many oil sands, especially if they are

[29] Ohern, D. W., Am. Assoc. Petr. Geologists Bull., vol. 2, p. 122, 1918.

lenticular, considerable confusion exists as to the position of the sand to which the name Peru properly applies. The best means of determining the correct application of such a term would be to determine to which bed it was generally applied in the field in which it originated. The term Peru sand presumably originated in the near-by field around Peru in Chautauqua County, Kans. Unfortunately only one log from this field is available in the files of the United States Geological Survey. This log is plotted in column 12, Plate LI. In addition to this the best evidence available is in a recent report of the Geological Survey of Kansas,[30] in which the Peru sand is said to be about 300 feet above the Bartlesville sand, and the Bartlesville is said to be about 200 feet above the Mississippian limestone. Another sand found to be productive at many places in Chautauqua County and there called the Red or Stray sand is said to lie 125 to 200 feet above the Peru sand. As these definitions are founded on knowledge of the application of the names over a wide area by many people, and as they conform with other evidence to be presented later in discussing what is believed to be the true Peru sand, they seem more reliable than the evidence of a single log from the Peru field and will therefore be accepted. Then the sand called the Peru in the log plotted in column 12, Plate LI (p. 378), is probably the Red or Stray sand. The lime overlying this sand is from its position apparently the Little lime. The sand reported as underlying the bed called the Little lime in the well in the southeast corner of sec. 33, T. 28 N., R. 11 E., corresponds in position approximately with this Red or Stray sand and may therefore be assumed to be its equivalent. At the time the report on T. 29 N., Rs. 11 and 12 E., was prepared records of wells penetrating beds at the horizon of this sand in the southern part of those townships indicated that the sand pinched out in that direction.[31] Since the preparation of that chapter, however, there has been a large production of oil, reported as great as 400 barrels a day, undoubtedly from beds at this horizon in secs. 26, 35, and 36, T. 29 N., R. 11 E. The authors have not seen the logs of these wells, but the reported depth of the producing sand, 905 to 915 feet, leaves little doubt that it is this Red or Stray sand. To the west also, in the West Mission Creek dome in T. 28 N., R. 10 E.,[32] this same sand has apparently yielded shows of oil. Operators in T. 28 N., Rs. 11 and 12 E., should therefore keep a careful watch for this sand. As the Little lime is generally recorded, if not named, by the driller, there should be no difficulty in identifying the Red or Stray sand, which, where present, occurs directly below it.

[30] Kansas Geol. Survey Bull. 3, pp. 245–246, 1917.
[31] U. S. Geol. Survey Bull. 686–W, p. 335, 1920.
[32] U. S. Geol. Survey Bull. 686–F, p. 52, 1918.

The identification of the Big lime in the logs of wells in this area has been made entirely from its position, as the drillers either did not report it or applied the name to some other bed. In these townships the top of the bed so named in this report lies from 1,150 to 1,250 feet below the horizon of the Iatan limestone. It is commonly divided into two beds, the upper about 35 feet thick and the lower averaging slightly thicker, separated by a parting consisting mostly of shale and averaging 30 feet thick, giving a total average thickness of about 100 feet. Some drillers call the upper bed the Big lime and the lower bed the Lower Big lime. All or a part of the shale parting is in places black shale. In T. 27 N., Rs. 10 and 11 E., no production of importance is reported from the Big lime. In T. 28 N., R. 10 E., and T. 29 N., Rs. 10, 11, and 12 E.,[33] oil and gas are reported from the upper bed, probably from a sand directly underlying it. In the logs of wells in T. 28 N., Rs. 11 and 12 E., the only production reported from the Big lime is a show of gas from the top of the lower member in the well near the west quarter corner of sec. 31, T. 28 N., R. 11 E.

Directly associated with the Big lime is the true Peru sand (see above, p. 374), but it is difficult to say from the records available what is its correct position. Shannon and Trout[34] state that the Peru sand of the Dewey-Bartlesville field probably comes within the shale member that separates the upper and lower limestone members. In the logs of wells in the northeastern part of Osage County, however, the name seems to be generally applied to a sandstone found in many places directly underlying the lower limestone member, or separated from it by 5 or 10 feet of shale. The name is used for a sand in this position in the logs of the two wells in the NE. ¼ NE. ¼ NW. ¼ sec. 6, T. 28 N., R. 11 E. (See columns 1 and 2, Pl. LI, p. 378.) In the log of the well in the SW. ¼ sec. 9, T. 28 N., R. 12 E., a sand is recorded in this position between the depths of 1,043 and 1,073 feet, though it is not called Peru. (See column 6, Pl. LI.) Finally, in the log of the well in the southeast corner of sec. 33 (column 5, Pl. LI) a water-bearing lime recorded in this stratigraphic position between 1,267 and 1,293 feet may be the equivalent of this bed, as limestones and hard sandstones are not always readily differentiated by the driller. The section described by F. C. Green[35] (column 8, Pl. LI) agrees with the interpretation given above, as he also places the true Peru sand in the Labette shale, which lies between the Big lime and the next generally recognized limestone below it, the "Oswego lime." In the interval between the two lime-

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[33] U. S. Geol. Survey Bull. 686–F, 1918; 686–W, 1920.

[34] Shannon, C. W., and Trout, L. E., Oklahoma Geol. Survey Bull. 19, pt. 1, p. 87, 1915.

[35] Green, F. C., A contribution to the geology of eastern Osage County: Am. Assoc. Petr. Geol. Bull., vol. 2, p. 119, 1918.

stone members of the Big lime in this area only very thin sandstones are recorded in a few of the logs. The upper member of the Big lime is undoubtedly the approximate equivalent of the Altamont limestone, the lower member the approximate equivalent of the Pawnee limestone, and the shale and sandstone interval separating them the equivalent of the Bandera shale, all three of which crop out together along the west side of Big Creek in the northwest corner of Craig County, about 40 miles to the east. Thence they continue southwest and south along Verdigris River past Nowata to Oologah, in Rogers County. The name Oologah formation is sometimes applied to the Altamont, Bandera, and Pawnee collectively, but the United States Geological Survey restricts the name Oologah to that more southerly part of their outcrop in which the intervening shale member has disappeared and the two limestones are united into one. (See table facing p. 360, columns 3 and 5.) The 100 feet or so of shale and sandstone lying between the lower member of the Big lime and the top of the "Oswego lime" below it is undoubtedly the approximate equivalent of the Labette shale. It is noteworthy that in the upper part of this shale, in the position of what is believed to be the true Peru sand, along its outcrop to the east, Ohern [36] has found a fairly constant sandstone. It thus appears that throughout northern Oklahoma this sandstone, which in this report is called the Peru sand, is considerably more continuous than those between the upper and lower members of the Big lime.

Generally in northeastern Osage County and vicinity the Peru sand below the lower member of the Big lime is a continuous bed of sand 30 to 40 feet thick and one of the important producing sands. In the well near the west quarter corner of sec. 31, T. 28 N., R. 11 E. (see Pl. LI, p. 378, column 3), the portion above a recorded parting of "lime shell" is reported to have yielded water and the portion below a show of oil, but the sand is nowhere productive in the townships under discussion.

At the base of the Labette shale lies probably the most constant limestone of the lower part of the Pennsylvanian series, called the "Oswego lime" by the drillers. It is undoubtedly the approximate equivalent of the Fort Scott limestone, which crops out about 50 miles to the east in the northeastern part of Craig County. According to Ohern [37] the lower part of the "Oswego lime" of Oklahoma was being deposited while the uppermost part of the Cherokee shale was being deposited in Kansas. The thickness of the "Oswego lime" as recorded in logs of wells in T. 28 N., Rs. 11 and 12 E., ranges from 62 to probably 145 feet but averages around 80 to 100 feet. Typically

[36] Ohern, D. W., Oklahoma Univ. Research Bull. 4, p. 17, 1910.
[37] Idem, p. 17.

the formation is divided into three limestones by shaly partings, locally black shale, and at its outcrop coal seams are in many places included in the shale partings. Sometimes more or less than two shale partings are reported, and some well logs record continuous limestone. (See columns 1, 2, and 6, Pl. LI, p. 378.) As brought out above (see text, p. 369, and fig. 51, p. 369), the interval between the horizon of the Iatan limestone and the top of the "Oswego lime" increases toward the southeast. The minimum recorded is 1,283 feet, in the northwest corner of T. 28 N., R. 11 E.; the maximum is 1,445 feet, in the southeast corner of sec. 33, T. 28 N., R. 11 E. In other parts of Osage County oil and gas are reported from the "Oswego lime," but in this northeastern part the only production mentioned is small quantities of gas, referred to in the report on T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E.[38] In the log of the well in the southeast corner of sec. 33, T. 28 N., R. 11 E. (see Pl. LI, column 5), a small quantity of water is reported from a 3-foot parting of hard shale in this lime.

The reported interval between the base of the "Oswego lime" and the top of the "Mississippi lime" ranges from 323 feet in the northwest corner of the area to 463 feet as recorded in the log of the well in the SW. ¼ sec. 9, T. 28 N., R. 12 E., but there may be some error in this part of that log. Except in this well the greatest interval recorded is 405 feet in the log of the well in the southeast corner of sec. 33, T. 28 N., R. 11 E. The interval may be expected to increase toward the eastern part of the area, according to figure 51 (p. 369), though not as rapidly as the interval between the top of the "Oswego lime" and the top of the "Mississippi lime," because, as shown by the numbers preceded by an O in that figure, the thickness of the "Oswego lime" usually increases somewhat in the same direction as the interval separating it from the "Mississippi lime." This interval consists mainly of shales, including some thin beds of black shale, thin limes, and sands. It is the equivalent of the Cherokee shale, which crops out about 50 miles to the east in eastern Craig County north of Vinita. (See table facing p. 360 and Pl. LI, columns 7 to 11.) In parts of Osage County and adjacent areas some of the most productive beds occupy this interval. Shannon and Trout [39] list as occurring in this interval the Bixler, Markham, Barnett, Bartlesville, and Burgess sands, with which they correlate the Squirrel, Glenn, Tucker, Squaw, Tanaha, and Meadows sands. The Dutcher and Rhodes sands may also belong in this part of the stratigraphic section. It is very doubtful whether any one of these names is always applied to the same bed. More probably there are at about the same horizon in

[38] U. S. Geol. Survey Bull. 686–F, text, p. 48, pl. 9, 1918.
[39] Oklahoma Geol. Survey Bull. 19, pt. 1, p. 84, 1915; pt. 2, table facing p. 526, 1917.

different wells unconnected lenticular sands to which the same name is applied.[40] Of the sands in the Cherokee shale enumerated above the Bartlesville sand or a sand called the Bartlesville is found over the widest area and is the most generally productive, and in this region a sand by that name is the only one reported to be productive. It is reported in logs of wells covering most of T. 27 N., Rs. 10 and 11 E., but is productive only in the center of the eastern part of T. 27 N., R. 10 E.,[40a] and along the south edge of T. 27 N., R. 11 E.[40b] In T. 27 N., R. 10 E., its top lies about 110 feet above the "Mississippi lime"[40c]; in T. 27 N., R. 11 E., about 160 feet.[40d]

Toward the north it appears to thin and lose its porosity, so that in T. 28 N., Rs. 11 and 12 E., it is not reported at all. It seems possible that a thin sand and a thin lime reported 151 and 160 feet, respectively, above the "Mississippi lime" in the wells in secs. 28 and 33, T. 28 N., R. 11 E. (columns 4 and 5, Pl. LI), may be the equivalent of the Bartlesville sand, but on account of the number and lenticularity of the sands in this part of the section the identification is doubtful. To the north in T. 29 N., Rs. 11 and 12 E., neither the Bartlesville sand nor any beds with showings of oil or gas are reported in this interval, while to the east and northeast in T. 28 N., Rs. 9 and 10 E., and T. 29 N., R. 10 E.,[40e] only traces of oil are recorded from sands in this part of the section. In the Peru field, about 10 miles to the north, in Kansas, a sand called the "Bartlesville"[41] lies about 200 feet above the "Mississippi lime." (See column 12, Pl. LI.) In drilling in T. 28 N., Rs. 11 and 12 E., the possibility of finding a productive sand about 1,650 to 1,750 feet below the horizon of the Iatan limestone should be considered.

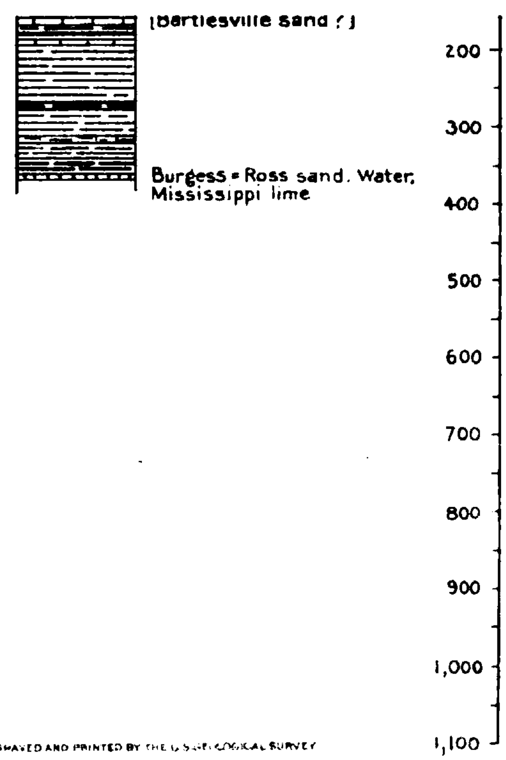
THE "MISSISSIPPI LIME" AND POSSIBLE UNDERLYING BEDS.

"Mississippi lime" is the name in general use for the series of limestones shown in the diagrammatic sections in Plate LIII. It is the deepest bed usually reached in drilling. There is some doubt whether the top of this limestone as encountered in wells is of Mississippian or basal Pennsylvanian age.[42] In fact, it is probably of different ages at different places, owing to the fact that the beds of Mississippian age were exposed to wearing away at the surface of

[40] As regards the Bartlesville sand cf. U. S. Geol. Survey Bull. 686–V, p. 307, 1919, and Berger, W. F., Am. Assoc. Petr. Geologists Bull., vol. 2, p. 123, 1918.
[40a] U. S. Geol. Survey Bull. 686–V, p. 307, pl. 48, p. 314, 1919.
[40b] U. S. Geol. Survey Bull. 686–T, p. 268, fig. 43, p. 267, 1919.
[40c] Idem, pl. 42, p. 262.
[40d] U. S. Geol. Survey Bull. 686–V, pl. 47, p. 306, 1919.
[40e] U. S. Geol. Survey Bull. 686–F, pl. 9, p. 48, 1918.
[41] Kansas Geol. Survey Bull. 3, p. 246, 1917.
[42] See U. S. Geol. Survey Bull. 686–A, p. xi, 1918; Bull. 686–T, pp. 262, 263, 1919; Bull. 686–V, pp. 308, 309, 1919; and Oklahoma Geol. Survey Bull. 24, pp. 21–51, 1915.

:rokee formation
:ludes Bixler, Markham, Barnet
ıd Burgess sands)

sissippian



RS. 11 AND 12

the earth for a long time before the beds of Pennsylvanian age were deposited on top of them, and the amount and duration of this erosion differed in different areas. Berger's map and discussion of the interval between the top of the "Mississippi lime" and the "Oswego lime"[43] gave much evidence as to the conditions that existed. Thus he has shown that in several places there are indications of the existence of old stream channels in the "Mississippi lime." Where these existed deeper members of the series are to be expected. In general also one would expect to find that the nearer any particular locality lies to the edge of the old Pennsylvanian basin the older, other things being equal, would be the bed forming the top of the Mississippian there and the fewer the basal Pennsylvanian beds that would be encountered, for submergence by the Pennsylvanian sea spread outward from the center of the basin, and while the deeper central parts of the basin were already under water the upper beds of the Mississippian were being worn away along the outer parts of the basin. In Plate LIII some of the principal logs of wells drilled into the "Mississippi lime," especially those that were carried farthest below its top, are represented, arranged in order from the shallowest to the deepest part of this probable old basin, as shown on Plate LII. With these diagrammatic logs is shown also a section of the Mississippian in northeastern Oklahoma generalized from the bulletin by Snider.[44] It has generally been assumed that the "Mississippi lime" of the drillers is the equivalent of the Boone limestone. If this is so, then the formations which lie between the Cherokee shale and the Boone limestone to the east are entirely lacking here, unless shales and limestones recorded above the "Mississippi lime" in the logs of some of the wells belong to these formations instead of to the Cherokee shale. The absence of thick limestones between the "Oswego lime" and the "Mississippi lime" in the logs of wells, even in the deepest part of the post-Mississippian basin,[45] is opposed to this last assumption. The Boone limestone is generally assumed to be a cherty limestone, yet only one of the logs (No. 10) represented on Plate LIII records chert or flint. A consideration of these logs with relation to the old post-Mississippian basin throws little light on the problem of the age in different wells of the beds called "Mississippi lime." The continuous thickness of limestone penetrated in the well at the extreme western edge of the basin (No. 1, Pl. LIII) and in the deeper eastern parts of the basin (Nos. 11 to 18, Pl. LIII) is about the same. The only noticeable difference is the occurrence apparently of more limestone and shale under the massive limestone to the west and of more

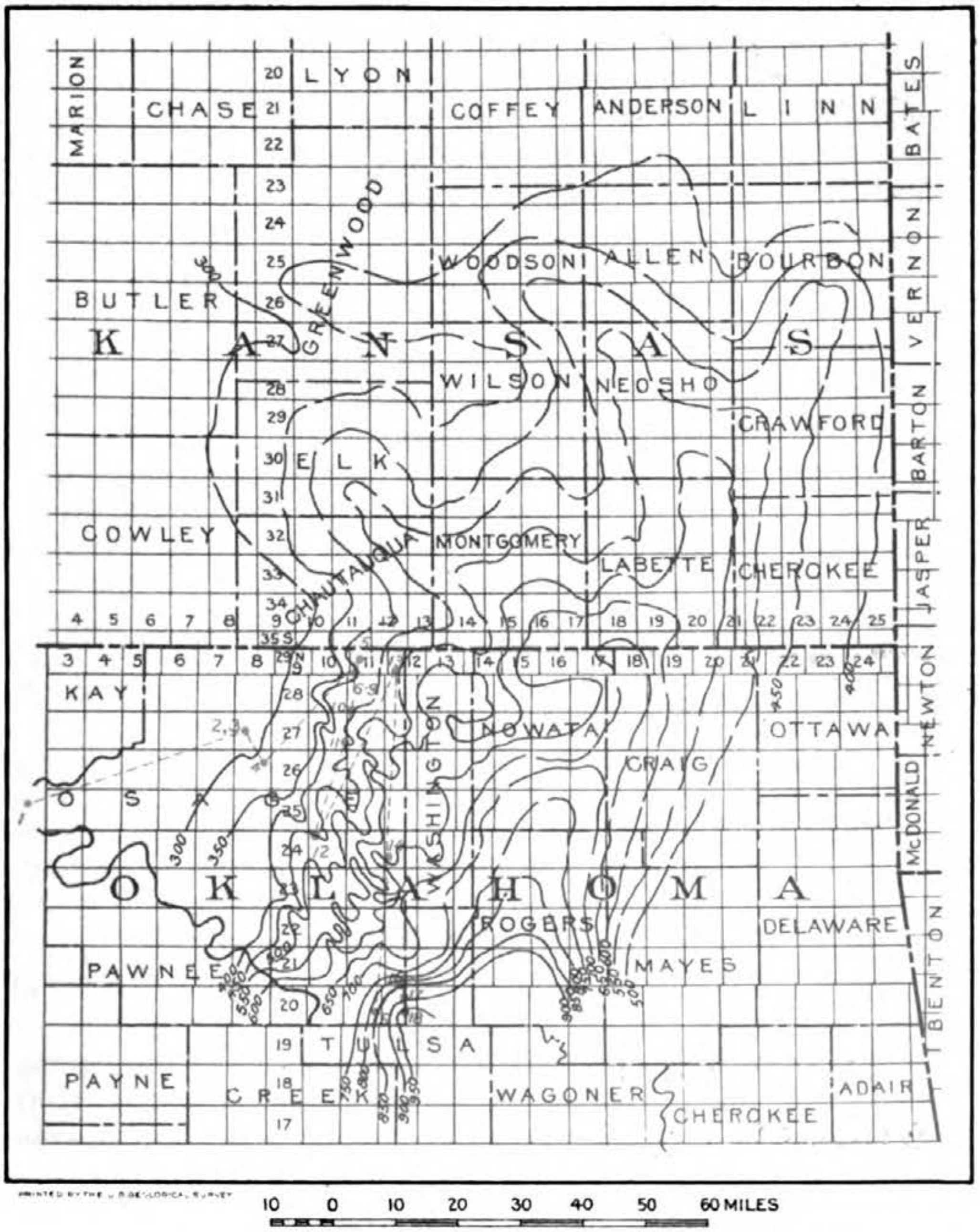
[43] Jour. Geology, vol. 26, pp. 618–621, 1918.
[44] Snider, L. C., Oklahoma Geol. Survey Bull. 24, pt. 1, plate facing p. 22, 1915.
[45] U. S. Geol. Survey Bull. 686–N, pl. 28, p. 174, 1919.

sandstones to the east; but this distinction is, for various reasons, of little use in determining the relative age. The one conspicuous fact calling for explanation brought out by these diagrammatic logs is that if the "Mississippi lime" is the equivalent of the Boone limestone, it is here underlain by a great deal of sandstone and light-colored shale instead of by the black Chattanooga shale. These sandstones may either occupy part of the interval represented to the east by black shale, or they may be sandstones in the Mississippian occupying part of the interval represented to the east by limestones. The former alternative seems the more probable and has therefore been made the basis of correlation on Plate LIII. The top of the first shale underlying the "Mississippi lime" has been taken as the top of the Chattanooga shale. If this assumption is correct, it implies a westward shallowing of the sea in which the Chattanooga shale was deposited, with increase of sand and lighter colored shale.[46]

If there is to be more deep drilling below the top of the "Mississippi lime" in the Osage region (and there should be), it becomes a very practical question, especially on account of the unconformity at the top of the "Mississippi lime," to know in what part of these formations a test hole is at any particular stage. This will be possible only if careful observations are made of the materials encountered in drilling. The recognition of chert where it is present will be helpful in identifying the Boone limestone, although the presence of chert will by no means positively identify the bed as the Boone. Fossils are particularly needed, and all larger fragments obtained from shots in the "Mississippi lime" should therefore be kept and examined for fossils. As far as time permits, the Geological Survey will be glad to help in the examination of these materials.

From the logs shown on Plate LIII and from the previous bulletins of this series, it appears that oil or gas may be obtained from beds at various horizons below the top of the "Mississippi lime." Of wells producing from the "Mississippi lime" in and adjacent to T. 28 N., Rs. 11 and 12 E., the most notable is the one in the southwest corner of sec. 31, T. 29 N., R. 11 E. (No. 7, Pl. LIII), which reported 225 barrels of oil, apparently from a sand 47 feet below the top of the "lime." Another directly adjacent (No. 8, Pl. LIII) obtained 1,500,000 cubic feet of gas, presumably from the upper 60 feet of the "Mississippi lime," though the log also records "little gas at 1,069 feet," which is about 600 feet above the top of the "Mississippi lime." In the southwest corner of the NW. ¼ sec. 31, T. 28 N., R. 11 E. (No. 10, Pl. LIII), gas was obtained from the

[46] For a summary discussion of the beds below the Pennsylvanian in this region, see Heald, K. C., Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: U. S. Geol. Survey Bull. 691, pp. 74–77, pl. 15, 1918.



SKETCH MAP SHOWING LOCATION OF WELLS DRILLED INTO "MISSISSIPPI LIME" IN OSAGE COUNTY, OKLA.

In relation to the probable basin in Mississippian rocks in which the lower Pennsylvanian sediments were deposited (to accompany Pl. LIII)

Curves represent interval between the top of the "Mississippi lime" and the top of the Fort Scott limestone ("Oswego lime")

Copied from Berger's map in Journal of Geology, vol. 26, page 619, 1918

"Mississippi lime," apparently from the upper 25 feet. Some of the biggest oil wells in Osage County have produced from the upper 50 feet of the beds underlying the main bed of "lime," 300 feet or more below its top, and it is quite possible that there are other producing sands not far below these. As stated in previous bulletins of this series, a test can therefore not be considered adequate until it has penetrated from 300 to 400 feet below the top of the "Mississippi lime," and wells now producing from higher levels should, if possible, before being abandoned, be deepened into the "Mississippi lime."

STRUCTURE.[47]

GENERAL CHARACTER.

The predominant attitude of the Carboniferous beds in the general region of Osage County and adjacent territory is a monoclinal dip to the west or northwest. In the townships under consideration the northward component is small, the dip being nearly west. Throughout this region the monoclinal dip is interrupted by eastward to southeastward reversals that produce folds with a general trend parallel to the northeasterly monoclinal strike, and by terrace-like or tonguelike structural features with a general trend either across or parallel to the strike. In T. 28 N., Rs. 11 and 12 E., the interruptions to the monoclinal dip are so numerous and irregular that they largely conceal it, but it appears most clearly along the east border of the area and along the westernmost tier of sections of T. 28 N., R. 12 E. The map (Pl. LIV, p. 394) shows the very irregular relations of the axes of folding to each other and the fact that in these townships the east-west trend predominates over the north-south.

RELATION OF TOPOGRAPHY TO STRUCTURE.

In view of the generally marked agreement between structure and topography in this region it is interesting to note to what degree the larger streams, like Caney River and Mission Creek, follow synclines in their courses. The structure here is not such as to afford a continuous syncline or series of contiguous synclines for a stream to follow, yet it is evident that Caney River has been drawn into the larger synclinal depressions, perhaps cutting its way between them

[47] As the townships covered by this report are bounded on three sides by townships whose structure has been described and mapped in earlier chapters of this bulletin, all the slight errors in measuring distances between beds and in mapping structure in these townships have been thrown into these two townships alone, with the result that there are two more contours in the surrounding townships than in these two. The excess contours in the surrounding townships have therefore been dropped where it seemed that they would least affect the form of the structure, namely, at the north edge of sec. 1, T. 28 N., R. 11 E., on both sides of the south corner common to secs. 35 and 36, T. 29 N., R. 11 E. (See Pl. LIV, p. 394; also U. S. Geol. Survey Bull. 686–W, Pl. XLIX, p. 330, 1920.) This is just north of the locality where the contours are drawn across the broad alluvium-filled valley of Caney River.

without much regard to structure. It is, moreover, quite possible that in some places where no synclines are shown in the projection of the structure across Caney River valley, especially in connection with the peculiar long anticlinal ridges in sec. 7, T. 28 N., R. 12 E., and sec. 12, T. 28 N., R. 11 E., minor structural depressions really exist.

The portion of Mission Creek in this area shows much less regard for the structure. In sec. 32, T. 28 N., R. 11 E., it lies in a syncline; in secs. 26 and 27 it follows the strike of the beds; and just beyond, in secs. 23 and 24, it lies at the edge of a synclinal depression; but over the rest of its course it seems to cut directly across monoclines or anticlines.

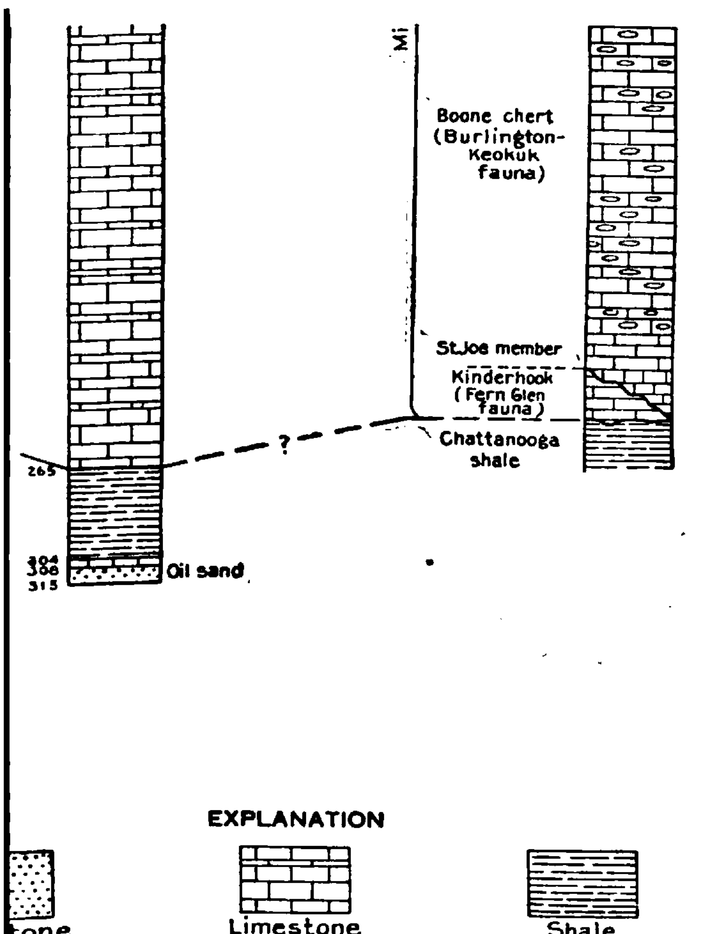
At best these broad, alluvium-filled valleys are a serious obstacle to the mapping of the structure. The areas covered by alluvium are therefore delimited on the structure map (Pl. LIV), and the structure of the beds underlying them is generally shown by broken lines. From what has been said above, and on account of the greater width of Caney River valley, it is evident that the projection of the structure across Caney River valley is much less certain than that across the valley of Mission Creek.

INDIVIDUAL FOLDS.

EAST MISSION CREEK DOME.

As the summit of the East Mission Creek dome lies in sec. 36, T. 28 N., R. 10 E., the dome has already been discussed in the chapter of this bulletin dealing with that township.[48] That description is therefore repeated here with slight modifications. The East Mission Creek dome occupies the SE. ¼ sec. 25 and most of sec. 36, T. 28 N., R. 10 E., and extends eastward into secs. 30 and 31, T. 28 N., R. 11 E. The crest of the dome lies about 1,000 feet west-northwest of the east quarter corner of sec. 36; the closure on the east amounts to about 40 feet. The dome has a fairly good gathering ground to the north but very little to the west and south. It has not been developed, but the conditions here are probably somewhat similar to those on the West Mission Creek dome, where there are several gas wells, each yielding from the "Mississippi lime" 750,000 to 4,500,000 cubic feet of gas as initial daily production, but no oil wells. The lower slopes of that dome do not seem to be productive, and some holes in an apparently favorable relation to the structure have been dry. The logs of some of the wells reported traces of oil from sands 35, 450, and 650 feet above the top of the "Mississippi lime." The depth to the "Mississippi lime" at the crest of the East Mission Creek dome is probably about 1,800 to 1,850 feet. Since field work in this area

[48] U. S. Geol. Survey Bull. 686–F, p. 53, pl. 8, p. 44, 1918.



[...] IN NORTHEASTERN OKLAHOMA.

was completed gas has been obtained from the east flank of this dome by a well in the southwest corner of the NW. ¼ sec. 31, T. 28 N., R. 11 E. The diagrammatic log of this well is shown in column 3, Plate LI (p. 378). Although experience has shown that the best production from anticlinal folds in this region is generally on the westerly flanks, the large gathering ground to the north of this dome may be favorable to the accumulation of oil on its east flank in sec. 31, T. 28 N., R. 11 E., and the producing area might also be extended to the northeast flank in the SW. ¼ sec. 30, T. 28 N., R. 11 E.

MUSGROVE TERRACE.

The Musgrove terrace lies in the E. ½ SE. ¼ sec. 31, and the W. ½ SW. ¼ sec. 32, T. 28 N., R. 11 E. It is a small tonguelike extension from the Musgrove anticline, in sec. 5, T. 27 N., R. 11 E.[49] The Musgrove anticline does not appear to be very favorable structurally, hence there is little reason for anticipating much production from this terrace, which is low and narrow and is cut off directly to the west by a syncline that separates it from the East Mission Creek dome.

CRANE DOME.

The Crane dome lies mainly in the southern part of sec. 29, T. 28 N., R. 11 E., with a slight extension into the NW. ¼ sec. 32. The summit is in the center of the E. ½ SW. ¼ sec. 29. Its axis strikes about northeast and may be regarded as the extension of the northeasterly branch axis of the East Mission Creek dome. The dome is weak, having a closure of only about 20 feet, broad, gently sloping flanks, and a low, flat western flank between the syncline separating it from the East Mission Creek dome and the summit. Toward the north-northwest it has a very extensive slope, but this slope is also the west flank of the Bowhan anticline described below. As oil in this country usually rises toward the southeast, the relations of the Crane dome are moderately favorable to the accumulation of oil. The "Mississippi lime" should be entered about 1,850 feet below the surface.

BOWHAN ANTICLINE.

The Bowhan anticline lies almost entirely in sec. 21, T. 28 N., R. 11 E. It is rather irregular in trend and shape. The main axis trends north and may be regarded as a north extension of the northeastward-trending axis of the Crane dome. From the south end, however, a branch runs off due east into a small domelike extension. The north, south, and northeast flanks are very short, being bounded by pronounced synclines that give the anticline an almost tongue-

[49] U. S. Geol. Survey Bull. 686–T, pl. 41, p. 258, 1919.

like character; but the west flank is very extensive, about 1½ miles wide and 110 feet high from the bottom of the syncline in the SE. ¼ sec. 18 to the top of the anticline. This west flank curves to the west and forms the north flank of the Crane dome. There is therefore some question which of the two folds would receive most of the oil that might rise up this flank. The best localities for tests would be near the center of the NW. ¼ or in the NW. ¼ NE. ¼ SW. ¼ sec. 21, T. 28 N., R. 11 E. Tests in about this location, if started below the ridge capped by the Bowhan sandstone, should encounter the "Mississippi lime" at a depth of about 1,800 feet. Unless some production is obtained from wells along the main anticline the small dome on the southeast end is to be regarded as unpromising.

TRUMBLEY ANTICLINE.

The Trumbley anticline lies in the W. ½ sec. 15, T. 28 N., R. 11 E. Its main axis trends north, but a westward extension of the south end forms a sort of connection with the Bowhan anticline. The east half of the anticline is cut off by a fault trending slightly west of north, with the east side thrown down and a sharp little syncline taking the place of the anticline on that side. If the Bowhan anticline proves unproductive, little is to be expected from the Trumbley anticline. It has the same broad west flank as the Bowhan anticline, but the upper part of this west flank is very flat, rather terrace-like in form, with a slope of not more than 40 feet in 1½ miles. The presence of a fault so near the summit is also a slightly unfavorable feature, as it might afford an opening for the escape of any oil or gas that may have risen toward the top of the anticline, or it may have facilitated the circulation of solutions that filled the pores of sands underlying the anticline. Should any oil or gas be obtained on the Bowhan anticline, however, the Trumbley anticline will be tested. One location for such a test would be along the west edge of sec. 15, especially adjacent to the west quarter corner. The outcrop of the Iatan limestone, as shown on the map (Pl. LIV, p. 394), runs near this corner along the edge of the valley of Caney River. A test might, therefore, start either on the limestone or in the valley bottom below it. The "Mississippi lime" should be encountered about 1,750 feet below the Iatan limestone. Another location would be in the west ¼-mile strip of sec. 16, as many of these terrace-like features in Osage County are found to be productive where the change from steep to flat dip takes place. A test in that strip would start either just above the Bowhan sandstone or just above the Iatan limestone. The top of the "Mississippi lime" may be expected at about 1,740 feet below the Iatan limestone, and the bed should be penetrated for at least 400 feet.

WOODRING ANTICLINE.

The Woodring anticline is a long, narrow plunging anticline whose axis extends approximately north along the west edge of sec. 34, T. 28 N., R. 11 E., and from the northwest corner extends northwest to about the center of sec. 28. Along its south half the west flank curves into the east-west strike which prevails to the south of it.[49a] The north half, however, is bounded on the west by a sharp syncline that gives a difference of elevation of 60 feet in a mile between the top and bottom of the west flank. The east flank is rather steep along its entire length but does not show a reversal dip of more than about 20 feet. Two tests holes have been drilled on this anticline—one in the northeast corner of the SW. ¼ sec. 28 (column 4, Pl. LI, p. 378), the other in the southeast corner of sec. 33 (column 5, Pl. LI). Both were drilled into the "Mississippi lime" and are reported dry. The log of the one in sec. 28 records the top of the "Mississippi lime" at a depth of 1,797 feet. It obtained a show of oil and gas in the upper 25 feet of the "Mississippi lime" but encountered water 75 feet below the top of the lime. The well in sec. 33 recorded the top of the "Mississippi lime" at 1,860 feet and was drilled 30 feet into it, which is not deep enough to test it adequately. The best locality for a further test would probably be in the northeast corner of sec. 33, at the break between the terrace-like top in the NW. ¼ sec. 34 and the steep west slope. A well in this location would be in the bottom of the valley of Mission Creek and should encounter the "Mississippi lime" at a depth of about 1,825 feet.

TABLE TOP ANTICLINE.

The Table Top anticline lies mainly in the northeastern part of sec. 4, T. 28 N., R. 11 E. It is one of the most promising folds in the area. Its presumptive extension to the south is concealed by the alluvium of the valley of Caney River. As projected from the contours on both sides of the valley, the axis runs nearly due north through about the center of the E. ½ sec. 4 from a point a little south of the south edge. Toward the north edge of the section the axis turns northeastward into a long tongue, mainly in sec. 33, T. 29 N., R. 11 E.[50]

The portion of the anticline in sec. 4, T. 28 N., R. 11 E., has a closure of about 40 feet. It appears to be nearly symmetrical with respect to the axis, and the flanks have a slope of about 60 feet in half a mile. Part of the west flank ends in a small synclinal tongue that is perhaps slightly faulted. The presence of this fault is some-

[49a] U. S. Geol. Survey Bull. 686–T, pl. 41, p. 258, 1919.

[50] See U. S. Geol. Survey Bull. 686–W, top of p. 343, and pl. 49, p. 330, 1920.

what unfavorable, as it may have permitted the escape of oil and gas or the circulation of water solutions which deposited mineral matter in the pores of the sand. The west flank, from which oil might have gathered, is not wide, but the sharpness of the fold assures the retention near the top of whatever oil might be present. The best localities for tests would be just west of the summit in the W. ½ SW. ¼ NE. ¼ sec. 4, T. 28 N., R. 11 E. These tests might start from 20 to 50 feet below the Iatan limestone, which caps the summit of the anticline, and should encounter the "Mississippi lime" at about 1,700 feet.

TONGUE ANTICLINE.

The Tongue anticline is a tonguelike plunging anticline of very irregular shape, with a general north to northeast trend. The axis runs slightly north of east from the south quarter corner of sec. 35, T. 28 N., R. 11 E., turns due northeast in the NE. ¼ sec. 35, and runs about a quarter of a mile into section 25. The flanks of this anticline are so short and the westward reversal of dip is so slight that it can not be considered of any importance as a source of oil or gas. There are records of two tests on this anticline—one a gas well, probably abandoned, in the NW. ¼ NW. ¼ SE. ¼ sec. 35, on the crest of the anticline, the other a dry hole in the southeast corner of the NW. ¼ SE. ¼ sec. 35, on the east flank at the head of the synclinal tongue which runs in from the northeast.

GORDON ANTICLINE.

Most of the Gordon anticline lies in sec. 26, T. 28 N., R. 11 E. It may be regarded as a northward extension of the Tongue anticline, which it offsets slightly to the west. The trend of its axis is about north-northeast from the center of the south edge of the SW. ¼ sec. 26 to and a little beyond the north edge of the NE. ¼ sec. 26. The anticline has a rather broad, steep west flank, three-quarters of a mile wide, with a difference of elevation of about 55 feet, and a broad, irregular east flank, about a mile wide at its widest part, extending in the form of a plunging terrace into the large Hay Hollow syncline in sec. 25. The closure is only about 10 feet. No adequate test of this fold has been made. There is a record of a dry hole or abandoned well with a showing of oil in the SE. ¼ SW. ¼ SW. ¼ sec. 23, which is almost in the bottom of the syncline that bounds the anticline on the northwest, and of another dry hole in the SE. ¼ NE. ¼ NE. ¼ sec. 27, still farther into the syncline. Some of the best locations for a test would probably be in the SE. ¼ NE. ¼ NW. ¼ sec. 26 and in the 10-acre lots directly to the north and south of that. Wells in this position may be expected to enter the "Mississippi lime" at a depth between 1,750 and 1,800 feet.

HAY HOLLOW SYNCLINE.

The Hay Hollow syncline is worth brief mention both on account of its size, which is unusual for this region, and on account of its relation to other synclines. It seems to lie along a fairly well defined line of synclines extending from the large one in secs. 14 and 11, T. 27 N., R. 11 E.,[51] through a smaller one in the northeastern part of sec. 1, T. 27 N., R. 11 E., and on across a north-south constriction at the back of the South Caney River terrace to the syncline in the southwestern part of sec. 6, T. 28 N., R. 12 E.

WHALEBACK ANTICLINE AND SOUTH CANEY RIVER TERRACE.

The Whaleback anticline is a large plunging east-west anticline lying in secs. 11, 12, 13, and 14, T. 28 N., R. 11 E. Its axis extends approximately from the NE. ¼ sec. 13 through the northwest corner of that section and on slightly beyond the west edge of sec. 14 a little south of the northwest corner. From this main anticline several smaller tonguelike plunging anticlines or broad, short terraces extend in northerly and southerly directions. Essentially the axis is the westward extension of the east-west axis of the South Caney River terrace in and adjacent to the NW. ¼ sec. 18, T. 28 N., R. 12 E.

On account of the uniform plunge of the anticline no part of it stands out as specially favorable for the accumulation of oil. Probably the South Caney River terrace, at the upper end, and some of the branch terraces are the most favorable sites. The only position along the main axis of the anticline that looks more favorable than others is near the middle of the north line of sec. 14, T. 28 N., R. 11 E., where there is a slight break in slope between the flat narrow top of the terrace and the steeper western nose. This position might be about 30 to 50 feet below a narrow ridge in sec. 14 capped by the Cheshewalla sandstone. Depths to different possible oil sands may therefore be estimated from figure 50 (p. 362) and figure 51 (p. 369). From these it appears that the "Mississippi lime" should be encountered at a depth of about 1,720 to 1,740 feet. A test might also be made in the northeast corner of sec. 15, at the outer edge of a small terrace-like expansion of the nose of the anticline.

The South Caney River terrace, which lies in the NW. ¼ sec. 18, T. 28 N., R. 12 E., and the E. ½ NE. ¼ sec. 13, T. 28 N., R. 11 E., is a small terrace of almost circular outline, pinched off at its back end by two north-south synclinal reentrants which almost produce a closed contour. The best point to test it would be at its front (outer) edge. An old test hole, shown on Plate LIV (p. 394), was put down

[51] U. S. Geol. Survey Bull. 686–T, pl. 41, p. 258, 1919.

at very nearly the position that would seem most favorable, appearing to be only 400 to 500 feet too far west. This test is known only from the iron leader found in the field projecting from the ground. No record is available, but the indications are that it was a dry hole. If this is true, it may be an unfavorable indication, but it is quite possible that the hole was not drilled deep enough.

GRAY, GORDON, AND SUNDOWN TERRACES.

Three small terraces, all with axes trending about south-southwest, run out from the south flank of the Whaleback-South Caney River fold. None of them is of much promise. Perhaps the least promising one is the most westerly, the Gray terrace, which lies mainly in the NW. ¼ sec. 23, T. 28 N., R. 11 E. Its flat, irregular west slope is terminated at its base by a pronounced north-south fault about three-quarters of a mile west of the axis of the terrace. There is no pronounced change of slope on any part of it—in fact, it is more of a tongue than a terrace.

The Gordon terrace is essentially a northward extension of the Gordon anticline, from which it is separated by a saddle probably not more than 10 feet deep. It lies mostly in the NW. ¼ sec. 24, T. 28 N., R. 11 E. Its exact form is uncertain, but it seems to be broad-topped with a short but steep west flank. So far as can be judged from what is known about its shape, the best place for a test would be at the top of this steep west slope, in about the SE. ¼ NW. ¼ NE. ¼ sec. 23, T. 28 N., R. 11 E. This would be on top of the Mission sandstone just above Mission Creek. A hole 800 feet or so to the south, in the NE. ¼ SW. ¼ NE. ¼ sec. 23, would be in the valley bottom of Mission Creek, perhaps 25 feet below the Mission sandstone, would be cheaper and more convenient to drill, and should be but little less favorable as a test. The "Mississippi lime" here lies probably about 1,700 feet below the Mission sandstone.

The Sundown terrace lies in the NW. ¼ sec. 19, T. 28 N., R. 12 E. Like the Gordon and South Caney River terraces it is pinched off at its back (north) end by two synclinal reentrants, which almost produce a closed contour. The west flank is unusually steep and shows a very abrupt change to the flat top of the terrace. As this west flank is nearly half a mile wide and has a difference of elevation of some 50 feet, the structural conditions appear favorable for the accumulation of oil. The best location for a test would be near the middle of the west edge of the NW. ¼ sec. 19, T. 28 N., R. 12 E. A test hole in this position would start in the alluvium of the valley of Mission Creek, 100 feet or so below the Mission sandstone, at the foot of a steep bank capped by that bed. The "Mississippi lime" should be encountered at a depth of about 1,625 feet.

MINOR FOLDS ON THE NORTH FLANK OF THE WHALEBACK ANTICLINE.

The width of the Caney River valley, which lies just north of the Whaleback anticline, makes it difficult to correlate the structure from one side to the other of the valley. Consequently, there is much doubt about the long tongues shown on Plate LIV (p. 394) as running north from the Whaleback anticline. The westerly tongue running along the boundary between secs. 10 and 11, T. 28 N., R. 11 E., seems well established as far north as the northwest corner of sec. 11, but beyond that nothing is known about it. What is known shows a narrow anticline with a rather gentle west flank at least a mile broad. Of the east flank less is known, but a gentle slope half a mile wide, with a reversal of dip of 30 to 40 feet, is indicated. The structure appears not unfavorable, and the anticline might be tested anywhere in the easternmost tier of 10-acre lots of the NE. ¼ sec. 10, T. 28 N., R. 11 E. A narrow ridge, capped by the Cheshewalla sandstone with the Iatan limestone overlying much of it, runs along this edge of the NE. ¼ sec. 10. For convenience and economy, the test should be made west of this ridge, as far below the Cheshewalla sandstone as possible. The best opportunity to get below the ridge in the east tier of 10-acre lots is in the NE. ¼ SE. ¼ NE. ¼ sec. 10, T. 28 N., R. 11 E. A test hole in this position should enter the "Mississippi lime" at a depth of about 1,750 feet.

The mapping of the long tongue running north through the E. ½ sec. 12 and into the SE. ¼ sec. 1, T. 28 N., R. 11 E., is much more questionable. This tongue is faintly indicated in the 1,130-foot contour, where it is mapped as turning north from the Whaleback anticline, on the south side of Caney River valley, but the continuation across the valley of the contours that form the tongue is, as indicated by the broken lines on the map, entirely hypothetical. The further possibility should here be mentioned that the relation of the contours on the two sides of Caney River valley, which makes it possible to interpret the structure as shown on the map, may be due to a convergence between the beds used for mapping the structure on these two sides, as the south side was mapped mainly on the Mission and Cheshewalla sandstones and the north side mainly on the Possum and Hulah sandstones. In any case, whether there is such a convergence or not, it is quite possible that most of the contours continue east and west across the assumed tongue, leaving a domelike uplift on the north side of Caney River, separated by a more or less pronounced east-west syncline from the practically smooth flank of the Whaleback anticline on the south side. In the lack of known elevations to prove the presence of the intervening syncline, however, it was considered best to assume the simpler structure indicated, though the occurrence of synclines on both sides and the apparent tendency of

Caney River to flow in synclines give much reason for assuming that the syncline is, nevertheless, there. In either case the best location for a test is just off the west edge of the terrace-like north end, near the west edge of the SW. ¼ SE. ¼ sec. 1, T. 28 N., R. 11 E. The north half of this strip is on the Possum sandstone and the south half in the bottom of Caney River valley, about 40 to 50 feet below.

The parallel north-south tongue in the NE. ¼ sec. 7 and SE. ¼ sec. 6, T. 28 N., R. 12 E., is even more uncertain than the one just discussed, all but the north end falling in the alluvium-covered area. It should be tested in the same position—that is, at the west edge of its terrace-like north end, in the NE. ¼ SW. ¼ SE. ¼ sec. 6, T. 28 N., R. 12 E. This falls in the valley bottom of Caney River, about 50 feet below a ledge of Hulah sandstone. The "Mississippi lime" should therefore be encountered here at a depth of about 1,630 feet.

LOST CREEK ANTICLINE.

The Lost Creek anticline is a moderate fold striking about northeast, which lies mostly in the NE. ¼ sec. 6, T. 28 N., R. 12 E., with a slight extension into T. 29 N., R. 12 E.[52] On account of its smallness and numerous irregularities the anticline may be somewhat unfavorable to the occurrence of oil or gas in commercial quantities near the summit. The best location for a test would be either in the NE. ¼ NW. ¼ NE. ¼ or the NW. ¼ NW. ¼ NE. ¼ sec. 6, T. 28 N., R. 12 E., or between the two faults shown in Plate LIV (p. 394) in the NW. ¼ SW. ¼ NE. ¼ sec. 6.

COON CREEK ANTICLINE.

The summit of the Coon Creek anticline lies in the NW. ¼ sec. 4, T. 28 N., R. 12 E. Thence it plunges with a north-northwest trend about a mile into T. 29 N., R. 12 E. It has been discussed at some length in the report on that township,[53] where the fact was brought out that there is some doubt about the existence of the eastward reversal shown on the map, and, as a consequence, about the existence of the entire anticline. This doubt is due to the fact that almost the entire area of the assumed east flank, except a small portion of the north end, lies under the alluvium of the valley of Coon Creek. If the structure is at all as indicated, the anticline is one of the best in the area under consideration. It has a steep west flank about a mile wide and a well-defined domelike summit, with a closure of 30 to 40 feet. It is possible that there is a north-northwesterly fault along the west side of the valley of Coon Creek cutting the anticline just east of the axis. Such a fault might have afforded a channel for the escape of oil and gas accumulated near the top of the anticline.

[52] U. S. Geol. Survey Bull. 686–W, pl. 49, p. 330, 1920.
[53] Idem, pp. 346–347.

One of the best locations for a test would be in the SW. ¼ NW. ¼ NW. ¼ or the NW. ¼ SW. ¼ NW. ¼ sec. 4, T. 28 N., R. 12 E. This would bring the mouth of the test hole a little above the Hulah sandstone, and the "Mississippi lime" should therefore be encountered at a depth of about 1,800 feet. Another position for a test would be about the center of the N. ½ sec. 5, T. 28 N., R. 12 E., at the west edge of the terrace-like expansion in the NE. ¼ of that section. A hole in this position would start in the valley bottom of Lost Creek north of the town site of Hulah and about 50 feet below the top of the Hulah sandstone. The "Mississippi lime" should therefore be encountered at a depth of about 1,700 to 1,720 feet. If either of these locations is found to be productive, the producing territory might be expected to extend all or part of the way toward the other.

DIVIDE TERRACE.

The Divide terrace is an east-west terrace that lies southeast of the Coon Creek anticline and extends through the S. ½ secs. 3 and 4 and the SE. ¼ sec. 5 and into the northern parts of secs. 9 and 10, T. 28 N., R. 12 E. The assumed central part of it, across its axis, is concealed by the alluvium of Coon Creek. So far as can be determined, it is unusually broad and flat, but nevertheless it does not look very favorable for the accumulation of oil, because it appears to have no well-defined outer edge where the dip abruptly flattens. Perhaps the nearest approach to such a change in dip is about in the center of the S. ½ sec. 5, T. 28 N., R. 12 E., and a test might be made there. A well in this position would start at about the same horizon as that suggested in the N. ½ sec. 5 on the Coon Creek anticline, and should encounter the "Mississippi lime" at the same or a slightly greater depth—that is, about 1,700 to 1,725 feet.

Another slightly favorable position for a test would be in the NW. ¼ SW. ¼ NW. ¼ sec. 9, T. 28 N., R. 12 E. The presence of a dry hole with salt water near the top of the "Mississippi lime" about half a mile to the south (see column 6, Pl. LI, p. 378) is, however, an unfavorable indication for this test. A well in this position would start about 80 feet below the top of the Hulah sandstone and should encounter the "Mississippi lime" at a depth of about 1,725 feet.

BUTTE DOME.

The Butte dome lies mainly in the SE. ¼ sec 8, T. 28 N., R. 12 E. It is the summit of a tonguelike southwestward-plunging anticline which branches off from the Divide terrace. The south and west extension of this anticline is concealed by the alluvium of the Caney River valley, but it appears probable that in the N. ½ sec. 17, T. 28 N., R. 12 E., the axis turns west and is practically continuous with the axis of the South Caney River terrace and Whaleback anticline, though a syncline in the area covered by alluvium may separate the two axes. This dome is small and not very promising and has already been tested (see Pl. LIV, p. 394) by a dry hole with considerable salt water that went 63 feet into the "Mississippi lime" in the NW. ¼ NW. ¼ SW. ¼ sec. 9, T. 28 N., R. 12 E. (see column 6, Pl. LI), and, as reported, by a gas well abandoned in the northeast corner of the SE. ¼ SE. ¼ sec. 8, T. 28 N., R. 12 E. There is much doubt of the existence of this gas well. The locality given is in a favorable position on the dome, but the occurrence of salt water in the other well so near by appears inconsistent with the presence of gas in this well. It may be more reasonable to assume that the dome is unproductive.

SUNDOWN ANTICLINE.

As represented on the geologic map (Pl. LIV) the axis of the Sundown anticline runs southeast from the NE. ¼ sec. 19 toward the southeast corner of sec. 20, T. 28 N., R. 12 E. The structure is very doubtful, however, because it was mapped from a thick series of lenticular sandstones exposed along a narrow, heavily wooded ridge lying between the alluvium of Caney River on one side and that of Mission Creek on the other. There appear to be two slight domelike summits along this axis, one around the west quarter corner of sec. 20, the other about the center of the S. ½ sec. 20. The former is by far the better, as it has a wide west flank; the latter appears to be situated at the head of a syncline. The former might be tested by a hole in the SW. ¼ SE. ¼ NE. ¼ sec. 19, T. 28 N., R. 12 E. A hole in this position would be near the foot of the ridge in the valley bottom of Mission Creek, about 100 feet below the Mission sandstone, and should encounter the "Mississippi lime" at a depth of about 1,700 feet. If this proves productive, drilling might be continued toward the other small anticlinal summit in the S. ½ sec. 20, T. 28 N., R. 12 E.

TRIPLET DOME.

The Triplet dome is a small uplift in the SW. ¼ sec. 16 and NW. ¼ sec. 21, T. 28 N., R. 12 E. The mapping of it is based mainly on a few elevations taken on a small hill bounded on three sides by alluvium, so that its form, like that of the Sundown anticline, is not well determined. A single contour incloses the elliptical summit, of which the longer axis measures about 1,500 feet. The extent of the west flank is entirely unknown, as this flank is covered by the alluvium of Caney River valley. The best location for a test, and that is not promising, would be on the northwest side of the small hill that lies on the west edge of the summit of the dome, about in the SW. ¼ SE. ¼ SW. ¼ sec. 16, T. 28 N., R. 12 E. A hole in this position would start on the

Hulah sandstone, which caps this hill, and should encounter the "Mississippi lime" probably at a depth of about 1,850 to 1,900 feet, though the distance is hard to estimate accurately in the absence of other wells in the neighborhood.

SCOTT ANTICLINE.

The Scott anticline is a small northeastward-plunging anticline lying mainly in the SE. ¼ sec. 36, T. 28 N., R. 11 E. Like the Tongue anticline, about a mile to the west, it is a plunging fold projecting from a broad northward-dipping slope south of it in the northern part of T. 27 N., R. 11 E.[54] The short, broad northwest slope and the lack of any closure on this anticline make it rather unfavorable for the accumulation of oil. There is no record of any development work on this fold. Probably the best locations for tests would be about the center of the SE. ¼ SW. ¼ and the southeast corner of the NW. ¼ SE. ¼ NE. ¼ sec. 36, T. 28 N., R. 11 E. In each of these locations the hole would start at a horizon between the tops of the Cheshewalla and Hay Hollow sandstones and should encounter the "Mississippi lime" at a depth of about 1,900 feet.

LOOKOUT ANTICLINE.

The Lookout anticline lies in the southeast corner of the area here considered. It is like many of the folds described in the preceding pages in that the details of its form are uncertain. It was defined mainly by elevations taken on the thick series of lenticular sandstones below the horizon of the Hulah sandstone exposed on narrow, heavily wooded ridges in the southern part of T. 28 N., R. 12 E., and correlated with elevations across the alluvium-filled valleys of Mission Creek and Caney River near their junction, a gap in places as great as 2 miles. It appears to be an elongated anticline plunging a little north of west. Near the east end of the narrow wooded ridge in the northern part of sec. 33, T. 28 N., R. 12 E., there is pretty good evidence for a reversal of dip, with a single closed contour marking the summit of the anticline lying mostly in the NE. ¼ of that section. It is reported that a dry hole was sunk just south of the north quarter corner of that section, at the edge of the closed contour shown on the geologic map (Pl. LIV). This would appear to be a favorable location for a test. Unfortunately only the record of the position of this hole, without any further information, is available. Moreover, the advantage that this location seems to possess from its position near the summit of the anticline is largely offset, on the one hand, by the uncertainty as to the actual existence of the wide north-northwest

[54] U. S. Geol. Survey Bull. 686–T, pl. 41, p. 258, 1919.

flank, which would be the principal gathering ground for oil toward the summit, as the area occupied by this assumed flank is almost entirely concealed by the alluvium of Mission Creek and Caney River, and on the other hand by the gentle, terrace-like slope of the plunging top of the anticline to the west. Oil coming from this direction might have been caught at the top of the west nose of the anticline, in the SE. ¼ SW. ¼ sec. 29, T. 28 N., R. 12 E., where the sharp change in dip occurs. A further test should therefore be made in the SW. ¼ SE. ¼ SW. ¼ sec. 29 or the NW. ¼ NE. ¼ NW. ¼ sec. 32, T. 28 N., R. 12 E. Tests in these locations might start on the Hulah sandstone near the top of the ridge or by moving a little farther west down the nose they could be started in the valley bottom, probably 100 feet or slightly more below the Hulah sandstone. The distance to the "Mississippi lime" is hard to estimate here, in the absence of any records of wells near by, but may be taken as about 1,850 feet below the Hulah sandstone. It must be admitted that the indications from the test at the northwest edge of the summit of this anticline, referred to above, are unfavorable, for even if the oil rising on the fold was caught at the west nose gas at least might be expected at the summit. Still, in view of the scant knowledge about this test another hole might be sunk near by, in the northeast corner of the NW. ¼ sec. 33, T. 28 N., R. 12 E. A hole in this position would start in the alluvium along the bank of Mission Creek near its mouth, at the foot of the high wooded ridge mentioned above, probably about 225 feet below the horizon of the Hulah sandstone. A rough estimate would place the "Mississippi lime" at a depth of 1,700 to 1,750 feet in this hole.

TPS. 26 AND 27 N., R. 12 E.

By P. V. Roundy, K. C. Heald, and G. B. Richardson.

INTRODUCTION.

This report describes an area 12 miles long and a little less than 3½ miles wide, comprising the portions of Tps. 26 and 27 N., R. 12 E., west of the east line of Osage County, Okla.

The field work in this area was begun in the fall of 1917 by G. B. Richardson, assisted by E. F. Lines, and was finished late in 1920 by P. V. Roundy and K. C. Heald, assisted by P. H. Moyer and W. W. Rubey. The area was mapped with telescopic alidade and plane table. Stadia traverses were run and checked by triangulation. A very few elevations were obtained by aneroid barometers.

The present surface in these townships has been cut from an eastward-sloping peneplain. The dissection is still in a youthful stage, for although some of the stream valleys are very well developed, with wide, flat bottoms, the interstream areas are broad and but little modified by stream channels, valley walls are commonly steep, and tributaries to the main valleys are narrow with steep gradients.

The area is drained by Butler Creek and its tributaries in the northern township and by Sand Creek and its tributaries in the southern township. The amount of water carried by these streams varies greatly, and in times of drought their flow fails altogether, but pools, some of them more than a mile long, are cut below the level of ground water in the beds of the main streams, and are a reliable source of supply for drilling operations and for stock.

The Missouri, Kansas & Texas Railway crosses T. 26 N., R. 12 E., from east to west. A siding near the west line of sec. 17 is a supply point for drilling operations in the immediate vicinity, but most of the supplies are hauled from the city of Bartlesville, which is only 1 mile east of the east line of the area and almost opposite the dividing line between the two townships.

The road net is fairly adequate, but the roads themselves need much improvement. Considerable money has been spent on such improvements, but failure to maintain them commonly results in their speedy destruction.

STRATIGRAPHY.

EXPOSED ROCKS.

Age and general character.—The rocks that crop out in this area are of middle Pennsylvanian age and correspond approximately to the lower part of the Douglas group, all of the Lansing group, and the upper part of the Kansas City group in the Kansas section. This correlation has been discussed by Goldman[1] in an earlier chapter of this bulletin. They comprise a series of sandstones, shales, and thin limestones, aggregating about 720 feet in thickness, as shown graphically in column 4, Plate LV.

Limestone forms only a small part of the geologic section, and shale is but slightly predominant over sandstone. Very few of the beds are good key beds for mapping structure or for correlation owing to lateral lithologic changes and to the lenticularity of the sandstones. The thin limestones in the upper part of the section are particularly unreliable. Individual beds were traced continuously over considerable areas, but only by the most painstaking, time-consuming work. The fossil content of some of the sandstones was particularly helpful in some small areas. Particular types of ripple marks and the direction of ripple marking were in places valuable aids. The tendency of beds to joint in a certain manner, to form a definite type of weathered surface, and to contain certain concretionary types, as well as other local characteristics, were helpful in making short-distance correlations. The associations of beds was constantly used to check determinations, and many closed circuits were run to prove the accuracy of the correlations.

Dewey limestone and overlying beds.—The Dewey limestone, which is the lowermost of the key beds used in mapping these townships, was seen only in a small area, about 1 mile north of Sand Creek in the eastern part of T. 26 N., R. 12 E. The outcrop at this place is probably separated from the rocks to the northwest by a fault, the surface expression of which is concealed by alluvium. It is a crystalline gray fossiliferous limestone, which at Dewey, Washington County, is over 20 feet thick. Where seen within the area mapped its thickness could not be determined but was probably less than 20 feet. The interval of 275 feet between it and the top of the Panther Creek limestone was determined by a measurement about 1 mile southeast of the area mapped. This determination may be slightly in error because of concealed faults, but it is checked approximately by many of the available well records.

The Dewey limestone helped comparatively little in determining the surface structure.

[1] Goldman, M. I., and Robinson, H. M., U. S. Geol. Survey Bull. 686–Y, p. 360, 1920.

GRAPHIC SECTIONS OF THE ROC
OSAGE COUNTY, OKLA., CO
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The interval between the Dewey limestone and the Torpedo sandstone is occupied by nonfissile shale with thin platy beds of hard, fine-grained sandstone that thicken locally. One of these intermediate sandstones is in places as much as 30 feet thick.

Torpedo sandstone.—The Torpedo sandstone[2] is a series of fine-grained, gray to yellowish gray sandstone, ranging in thickness from about 25 to 70 feet. In some sections it contains many thick shale partings; in other sections it is nearly a continuous series of medium thick to massive sandstone beds with one or two prominent shale partings. Usually it makes two very prominent benches. Several of the beds are beautifully ripple marked.

Panther Creek limestone.—The limestone to which the name Panther Creek is herein applied either rests on the Torpedo sandstone or is separated from it by a thin shale. It is named from Panther Creek, in the southwestern part of T. 26 N., R. 12 E., where it is well exposed along the valley rim to the east and to the west. This limestone in T. 26 N., R. 11 E., was called the Stanton (?) limestone by Clark.[3] Later Goldman and Robinson[4] called a limestone in T. 28 N., R. 12 E., the Stanton (?) limestone, basing their correlation more on evidence tending to connect their limestone with the Stanton of the Kansas section than on evidence tending to prove the correlation of their limestone with that mapped by Clark. The mapping of the present area has definitely proved that the Stanton(?) limestone of Goldman is approximately 190 feet higher in the stratigraphic section than the Stanton (?) of Clark. The evidence presented by Goldman and Robinson tending to correlate their Stanton (?) limestone with the Stanton limestone of Kansas, although not conclusive, is still fairly convincing.

Fossils collected from these two limestones were referred to G. H. Girty, who reports in part as follows:

> The faunas in a general way would tend to locate both limestones above the Kansas City formation—that is, in the Lansing formation—and would tend to correlate the higher limestone (the Stanton (?) limestone of Goldman) rather than the lower limestone (the Stanton (?) limestone of Clark) with the Stanton limestone of the Kansas section.

With this evidence at hand it is inadvisable to continue the use of the name Stanton (?) limestone for the limestone mapped in T. 26 N., Rs. 11 and 12 E.

The Panther Creek limestone is thicker and is of more importance as a key bed in this area than to the south and to the west. In some sections it attains a maximum thickness of 14 feet. Usually the lower part is a rather siliceous impure limestone that weathers to an

[2] Hopkins, O. B., U. S. Geol. Survey Bull. 686–H, p. 76, 1918.
[3] Clark, F. R., U. S. Geol. Survey Bull. 686–I, p. 95, 1918.
[4] Goldman, M. I., and Robinson, H. M., U. S. Geol. Survey Bull. 686–Y, p. 367, 1920.

orange color. The upper part is a purer and lighter-colored limestone, in places almost white. The entire limestone contains an abundance of crinoid-stem segments and some other fossils. At the top occurs a very fossiliferous bed, partly argillaceous. The plates of crinoid cups and arms are especially abundant in this bed which also contains many Foraminifera, Ostracoda, and Bryozoa and smaller numbers of some other forms.

The several beds of the Torpedo sandstone and the Panther Creek limestone were the most useful key beds in mapping the southern township.

Beds between the Panther Creek limestone and the Revard sandstone.—Massive sandstones and thick shales compose the rocks for the first 150 feet above the Panther Creek limestone. The sandstones are in part locally replaced by shales.

A shale zone occupies the interval from 150 to 280 feet above the Panther Creek limestone. This zone is rather constant in thickness in the area mapped. It contains some sandstones and many thin sandy limestone beds, which individually are of very small extent. They usually range from 1 to 3 feet in thickness, and many of them contain numerous brachiopods. Usually one or two of these limy lenses are present in a single section, and in a few sections there are more. Few of these limestone beds are reliable for use in mapping. One of them, however, which is decidedly less sandy and contains more gastropods than the other beds in this zone, proved to be a reliable horizon marker over a part of the area. This bed is well exposed on the south escarpment north of Butler Creek in the eastern part of T. 27 N., R. 12 E. The limestone in T. 28 N., R. 12 E. described by Goldman and Robinson as the Stanton (?) limestone. occurs in this zone. Its relation to the Stanton limestone of the Kansas section is explained in connection with the Panther Creek limestone (p. 397).

The Torpedo (?) sandstone of the same authors, which occurs just below their Stanton (?) limestone, thins and locally disappears south of the area they describe. It is, of course, much higher in stratigraphic section than any of the sandstones exposed at Torpedo, the type locality of the Torpedo sandstone.

Revard sandstone.—The Revard sandstone[5] in T. 26 N., R. 10 E., is a massive sandstone 30 to 40 feet thick. In its northeastward extension into T. 27 N., R. 11 E., it thickens and in places contains much shale.

In T. 27 N., R. 12 E., the Revard sandstone is about 70 feet thick. It becomes differentiated into three distinct medium-heavy to massive bedded sandstone zones, separated by shales containing

[5] Clark, F. R., U. S. Geol. Survey Bull. 686–I, p. 94, 1918.

thin sandstones. The top of the Revard, which is about 350 feet above the Panther Creek limestone, for the purposes of mapping was considered to be the top of a massive bed which over most of this township is the actual top of the formation. However, in a few places a more loosely cemented sandstone is found above the main bed. This local sandstone showed very indistinct bedding planes, weathered into large rough knobs, and could as a rule be readily distinguished from the main bed that was considered to be the top. The top of the middle sandstone zone lies 42 feet below the top of the Revard. This zone is usually easier to follow in the field than the upper bed. Of the three it is usually the thickest and most massive. The lower sandstone zone, however, is the best one in the Revard to use in mapping. In fact, it proved to be the best key bed in this township. The top, which is usually ripple-marked, is about 63 feet below the top of the Revard and nearly everywhere makes a prominent bench. Its upper part is composed of massive platy sandstone beds. Just above this ripple-marked bed and separated from it by a foot or so of shale is a very thin sandstone band which is crowded with fossils. This band is distinguished from many other fossil zones by containing *Pleurophorus* (probably *P. subcostatus*) in great abundance. Unfortunately this fossiliferous bed is not everywhere present. The top beds of this zone are massive but remarkably smooth bedded. The lower beds of the Revard sandstone are typically exposed in the northeastern part of T. 27 N., R. 12 E., where they usually form the rims of the steep escarpments.

In some parts of T. 27 N., R. 12 E., either or both of the shales that separate the three sandstone zones are partly (in a few exposures almost entirely) replaced by heavy-bedded sandstone. Under these conditions it was found difficult, though not impossible, to distinguish and map all three zones.

In T. 28 N., R. 12 E., the Revard sandstone breaks up into more sandstone zones separated by shales, so that, for purposes of oil geology, it is better considered as several separate sandstones. In the work on that township parts of the Revard sandstone were mapped under the names Mission, Possum, Gap, and Hulah. The Mission sandstone is equivalent to the top of the Revard and the Hulah sandstone is the same as the sandstone 42 feet below the top of the Revard in the township to the south.

Cheshewalla (?) sandstone and underlying beds.—In the northwestern part of T. 27 N., R. 12 E., a high point and ridge are capped by a massive sandstone which is probably the lower part of the Cheshewalla sandstone.[6] It is almost indistinguishable in appearance from parts of the Revard sandstone. Between the base of the

[6] Winchester, D. E., and Heald, K. C., U. S. Geol. Survey Bull. 686–G, p. 61, 1918.

Cheshewalla (?) sandstone and the top of the Revard sandstone are thick beds of shale with thin, platy sandstones, none of which are prominent.

ROCKS NOT EXPOSED.

At least 703 wells have been drilled in the Osage County portion of these two townships, but the writers have been able to obtain records of less than half of them. Of the records obtained a few show only casing data and total depth, and some show only the producing portion of the Bartlesville sand. About half of them indicate the position of the "Oswego lime." Others are more or less complete. The character of the rocks is indicated in Plate LVI, which shows graphically the driller's interpretation of the rocks penetrated in this area These records are so alined that the top of the "Oswego lime," which is used as a datum, is a horizontal plane. Logs 1 to 14 represent wells along a north-south line through the portion of the area where the variation in interval between the top of the "Oswego lime" and the top of the Bartlesville is small. Logs 15 to 18 indicate one of the lines of rapid increase in this interval. Logs 2 and 4 are records of the deepest wells drilled in these townships. (See fig. 52.)

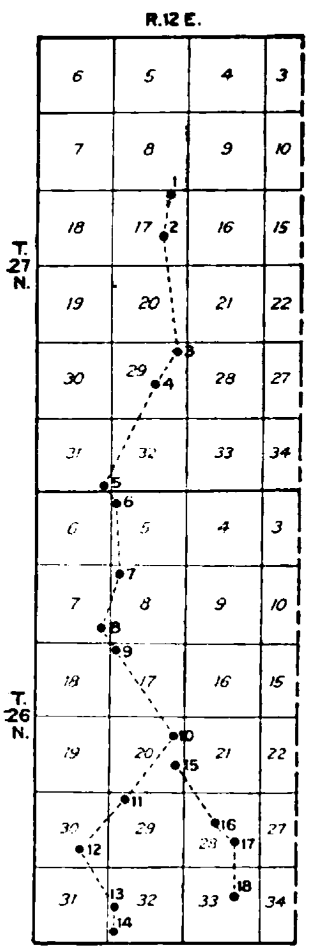

FIGURE 52.—Diagram showing location of wells whose logs are given in Plate LVI.

"Oswego lime."—"Oswego lime" is the drillers' term for the probable equivalent of the Fort Scott limestone of the Kansas section. This limestone is probably the most carefully recorded and most widely recognized underground horizon marker in eastern Osage County. In the townships here considered it is generally recorded as being 50 to 100 feet thick, though one log gives a thickness of only 40 feet and five logs indicate a thickness of more than 100 feet. Though usually recorded as a solid limestone, a few logs record one or two shale breaks in it. The interval between the top of the Panther Creek limestone and the "Oswego lime" is 1,170 feet in sec. 31, T. 26 N., R. 12 E. To the north and to the east this interval decreases by 15 or 20 feet to the mile, being about 1,050 feet in sec. 5 and 1,000 feet in sec. 3. In sec. 17, T. 27 N., R. 12 E., it is about 950 feet. In some of the wells in these townships a little gas has been found in the "Oswego lime," and elsewhere in Osage County it contains notable amounts of both oil and gas.

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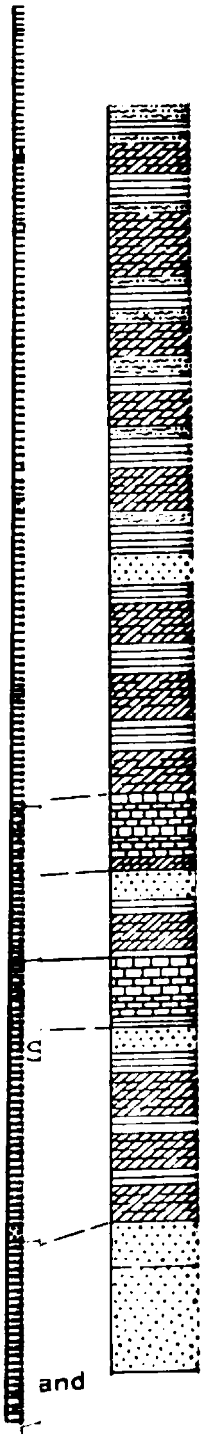
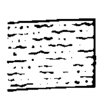
Pennant, Skelton-Moore

W Well No.

Sec. 17, T ...c. 32, T. 26 N.





Soil

E., OSA

Beds above the "Oswego lime."—The beds between the Dewey limestone and the "Oswego lime" consist of an upper shale series with thin limestones and sandstones, a massive limestone known as the Big lime, and a lower shale containing a sandstone known as the Peru sand. The logs vary so greatly in their interpretation of the upper shale series that only a few general deductions are possible. The limestones and sandstones together comprise only about one-third of the series, the remainder being gray, blue, brown, and black shales. Three of the thin sandstones locally show a little gas, and two have furnished showings of oil. One of the sandstones yielded large quantities of oil in the Wiser Hill pool. (See pp. 414–416.)

The Big lime is a white to gray limestone 60 to 100 feet thick. Only a few logs indicate one or two shale "breaks" in it. The top of this limestone is about 200 feet above the top of the "Oswego lime." As recorded in the logs this interval ranges from 150 to 250 feet, but no actual convergence appears to be indicated. The Peru sand with shale occupies the interval between the Big lime and the "Oswego." This sand, recorded in less than half of the logs, ranges from 10 to 100 feet in thickness. Considerable oil has been produced from it, especially in the southern and eastern parts of T. 26 N., R. 12 E.

Beds between the "Oswego lime" and the Bartlesville sand.—A sandstone lens, called by the drillers the Squirrel sand, attains a maximum thickness of 120 feet in this area. Its top lies from 72 to 140 feet below the top of the "Oswego lime." This sand is not recorded in as many logs as the Peru sand. It is of very little importance as an oil producer.

The rocks between the Bartlesville sand and the Squirrel sand, or between the Bartlesville sand and the "Oswego lime" where the Squirrel sand is absent, are shales with a few thin limestones. Occasionally a thin sand is recorded.

Bartlesville sand.—A sand that occurs between 1,200 and 1,300 feet below the surface at Bartlesville, Okla., is called the Bartlesville sand by the drillers. It is the most productive sand in this region and one of the principal oil and gas yielding sands of Oklahoma. Its top in this area lies from 330 to 460 feet below the top of the "Oswego lime." Although part of this apparent variation may be due to the drillers' interpretation of what is the top of the Bartlesville sand, most of it is probably due to convergence in the intermediate shale series. The interval is least in an area about 2 miles long from north to south and less than half a mile wide, about in the middle of the mapped part of T. 26 N., R. 12 E. From this area the increase in interval between the top of the "Oswego" and the top of the Bartlesville is most rapid to the southeast and to the northeast, less rapid to the southwest and the west, and slowest to the south and the north, and to the east from the south end of the area.

The Bartlesville sand in this region is generally recognized as consisting of two distinct portions, in many places separated by a shale break. The upper part, called by most drillers the "gas sand," is usually much thinner than the lower part, which is called the "Bartlesville oil sand." Some logs indicate the upper and some the lower part as the darker colored. The total thickness of the Bartlesville sand, as recorded in logs of wells which are said to have penetrated the shales below it, ranges from 10 to 170 feet in these two townships. The sand is thinnest in the center of the western part of T. 27 N., R. 12 W., where the drillers claim that the "gas sand" is absent.

Rocks between Bartlesville sand and "Mississippi lime."—The logs of the deeper wells indicate that the top of the "Mississippi lime" occurs from 20 to 200 feet below the base of the Bartlesville, though the most frequently mentioned intervals lie between 60 and 100 feet. This interval is usually indicated as occupied by shale or "slate." A few logs, however, record a sand, 30 feet or less in thickness, just above the "Mississippi lime." This sand is called the Burgess sand in these townships. In places it yields a little oil.

"*Mississippi lime.*"—As known in this area, the "Mississippi lime" consists of limestone interbedded with chert and sandstone. The limestone is usually more or less cherty. Gas is obtained in considerable quantities from the upper part of the "Mississippi lime." Only two wells have penetrated it to any depth below the gas horizon. These two wells, in secs. 17 and 29, T. 27 N., R. 12 E., have drilled through 273 feet and 305 feet, respectively, of the lime without passing through it. Neither well appears to have penetrated a thin shale series such as usually lies above the "Wilcox" sand to the south, nor does the Ordovician limestone seem to have been reached. Both are dry holes. It is unfortunate that these wells could not have been drilled to about 350 feet below the top of the "Mississippi lime," as this might have demonstrated the presence of a deep productive bed. From a study of published data [7] on the "Wilcox" sand and the "300-foot break" in the "Mississippi lime" as well as a review of the logs of many of the deep wells in Osage County, the writers are of the opinion that the "Wilcox" sand may

[7] Greene, F. C., Oklahoma's stratigraphic problems: Oil and Gas Jour., vol. 18, No. 49, p. 54, 1920. White, L. H., and Greene, F. C., Correlation of the Wilcox sand in the Okmulgee district with the Osage: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 3, p. 399, 1921. Aurin, F. L., Clark, G. C., and Trager, E. A., Notes on the subsurface pre-Pennsylvanian stratigraphy of the northern Mid-Continental oil field: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, p. 117, 1921.

be present in these townships. If so, it probably lies about 350 feet below the top of the "Mississippi lime." Tests should be made on the Jessie Creek anticline and the Panther Creek anticline (see pp. 410, 411) either by deepening some of the present wells or by new drilling on the crests of the anticlines, to a depth 400 feet below the top of the "Mississippi lime." Great care should be exercised to obtain a complete and accurate record of the strata below the top of the "Mississippi lime." If this is done, two tests at the localities mentioned would be almost sure to prove the presence or absence of oil-bearing beds at the "Wilcox" horizon.

STRUCTURE.

GENERAL FEATURES.

In the eastern part of Osage County 1,500 to 2,000 feet of rocks. composed largely of shale, rest on a series of pre-Pennsylvanian strata consisting mainly of limestones with some sandstones, cherts, and thin shales. These in turn are underlain by crystalline rocks. In response to the various deformational forces these lower hard rocks, or competent strata, have been folded and faulted. The overlying softer or relatively incompetent Pennsylvanian rocks were naturally similarly deformed, but probably with a magnitude and complexity of structure decreasing upward, owing in part to the compression and squeezing out of the shales. However, small faults in the lower competent rocks might have resolved themselves into more complicated structure in the higher rocks. Therefore, the structure of the surface beds should be and probably is considerably different in detail from that of the lower beds.

To portray the deformation absolutely, a bed that was deposited in a perfectly horizontal position is needed as a datum plane. Very few beds are being deposited in such a position to-day, and probably none of the Pennsylvanian beds of Osage County were deposited in such a position. It is evident that the surface beds in the two townships here described must have been deposited more unevenly than those of the western Osage country, and therefore any contour map of the surface beds in these townships obviously could not portray the minute details of structural conditions if structure is defined as attitude due to deformation alone. However, the oil geologist and the person interested in the occurrence and recovery of oil are more interested in the present attitude of the rocks relative to sea level than in the details of deformation. Therefore, the term "structure," as used in this paper and in the previous papers in this bulletin, refers to the attitude of the rocks relative to sea level, regardless of whether that attitude is due to deposition or to deformation.

SURFACE STRUCTURE.

The 10-foot contour lines shown on Plates LVII and LVIII are based entirely upon observations made on rocks that crop out at the surface. They represent the elevation above sea level of a hypothetical bed 542 feet below the top of the Revard sandstone. This datum plane is 375 feet lower than the datum plane used in T. 25 N., R. 12 E., 465 feet lower than that used in Tps. 26 and 27 N., R. 11 E., and 765 feet lower than that used in T. 28 N., R. 12 E. This relation causes the contours to interfinger with those of the bordering townships where the structure is similarly interpreted. Along the east edge of T. 27 N., R. 11 E., however, a convergence of higher beds, which are absent from T. 27 N., R. 12 E., caused a different interpretation of the structure. This difference is also accentuated because the datum plane used west of the line between the two townships is above the surface of the ground, and the datum plane used east of the line is below the surface.

Several faults in this area are clearly indicated by the actual displacement of beds in one or more places along the fault line. The existence of other faults is proved by the relations and elevations of adjacent beds.

A small fault, in the northern part of sec. 19, T. 27 N., R. 12 E., has a maximum throw of about 10 feet. It is less than half a mile in length, strikes a little west of north, and probably has but little effect on the collection and recovery of oil.

A fault about 1¾ miles long, in secs. 16, 21, and 22, in the same township, is of the scissors type and has a maximum throw of a little more than 15 feet. Its main importance appears to be in relation to the collection of oil in a shallow sand, as noted in the description of the Wiser Hill pool (p. 415).

The outcrop of the Dewey limestone in the northwest corner of sec. 15, T. 26 N., R. 12 E., and its relation to the exposed beds to the northwest appear to demand a fault in the narrow alluvium-covered area between these exposures. The throw of this fault is probably 50 feet or more. The southwestward swing of Viza Creek is probaby due to this fault line. The direction of the two contour lines on the island of Dewey limestone is purely hypothetical, as an undetermined amount of the limestone has been eroded from part of this area—enough, at least, to make it impossible to determine the direction. High initial production of oil in the eastern part of sec. 9, just west of this line, is at least additional suggestive evidence of this fault.

Three faults, which are probably but not certainly connected, extend from the SE. ¼ sec. 20, T. 27 N., R. 12 E., through secs. 29, 28, and 33 in this township and secs. 5, 8, 7, 18, and 19 in the township to the south. The total length of the three faults is therefore about 7 miles. The end components of this system are northwest-southeast faults. The northern fault was seen in two places, with a downthrow on the west side of about 10 feet in the SE. ¼ sec. 20 and a maximum downthrow on the east side of about 30 feet in the SW. ¼ sec. 28. The conclusion that these two parts of this fault are connected under the cover of alluvium is based on observed directions of the fault strikes.

The southern fault of this system, in T. 26 N., R. 12 E., likewise has definite evidence of displacement with a maximum throw of about 20 feet. Although the writers believe it is confined to sec. 19, T. 26 N., R. 12 W., it may extend under the alluvium into sec. 18. The middle fault has a maximum throw of more than 200 feet in sec. 18, T. 26 N., R. 12 E. It extends northeastward into sec. 33, T. 27 N., R. 12 E. Except in sec. 18 the displacement is small, mainly less than 10 feet. There is a possibility that instead of being a single long fault this is a series of small faults with one major fault, all in a straight or nearly straight line. The fault line was actually observed only in the southern part of sec. 5. In sec. 18 the fault line occurs in the alluvium-covered area adjacent to Sand Creek. The relations of the well-exposed beds on each side of the creek flat, however, make the conditions perfectly obvious. The fault is of the compound scissors type. Unfortunately, the points where the ends of this fault or line of faults meet the smaller, northwest-southeast faults, are concealed by alluvium.

SUBSURFACE STRUCTURE.

Elevations of about two-thirds of the wells drilled in these townships were obtained by the writers. Unfortunately the logs of many of these wells appear to be unobtainable, and some of the records that are available are so incomplete as to be of little use. However, enough information has been gathered to reveal some very interesting facts regarding the underground structural conditions. As indicated on page 401, a convergence between the Bartlesville sand and the "Oswego lime" centers in T. 26 N., R. 12 E., where the interval between the tops of these beds is as small as 330 feet. This convergence is practically continuous from an area at least as far south as T. 15 N., R. 12 E., where the interval exceeds 800 feet, if the writers are correct in assuming that the Bartlesville sand of the Bartlesville region is in part equivalent to the Glenn sand of the Okmulgee region. Westward from T. 26 N., R. 12 E., the interval probably increases more slowly. However, there is considerable doubt as to the continuity of the sandstone beds in the Cherokee shale in that direction and also to the east. Probably a number of different beds or lenses have been called Bartlesville sand. The evidence at present available suggests that these sandstone lenses in the Cherokee shale of eastern Osage County were deposited as long, narrow north-south sand bars which, at least in places, overlap.

The upper part of the Bartlesville sand is shown by contour lines on Plates LIX and LX. In mapping this structure some logs were used which gave only the depth of the top of the producing sand, and in connection with such logs estimates were made as to the depth of the top of the Bartlesville sand (top of the so-called "gas sand"). This depth varies even between adjacent wells and much more between widely separated areas. It must therefore be recognized that, although the maps show the general surface of the Bartlesville sand, they may be somewhat inaccurate in minor details. The uneven surface and channels in this sand would of course make its surface differ considerably from that of the contoured upper beds, as shown on Plates LVII and LVIII.

In T. 26 N., R. 12 E., so many of the logs fail to indicate the position of the "Oswego lime" that no contours on that bed are shown. In T. 27 N., R. 12 E., where sufficient information exists, the tops of both the Bartlesville sand and the "Oswego lime" are contoured. In the Wiser Hill pool the "shallow sand" offers the only evidence sufficient for drawing underground contours.

A comparison of the major structural features shown on both the subsurface and surface maps shows that there is a general resemblance. However, these features are slightly displaced horizontally and are of somewhat greater magnitude and complexity in the lower beds than in the surface beds. The subsurface evidence would suggest that the throw along fault lines is greater in the lower beds than at the surface. Unfortunately, the writers were unable to obtain many logs of the wells in sec. 18, T. 26 N., R. 12 E., where the greatest surface fault throw exists.

No attempt will be made to present positive statements regarding the relations of surface structure to that of the oil-bearing beds, for the data available in this area are too incomplete to justify it. The relations suggested below are far from established, but the available evidence indicates their probability, and they should be borne in mind by students of adjacent areas.

Domes and closed anticlines expressed in the surface beds are almost invariably associated with domes in the oil-bearing beds, although these domes rarely coincide exactly. The doming in depth is, as a rule, much sharper than that at the surface. For example, the dome in the Bartlesville sand under the Jessie Creek anticline has a closure of 30 feet or more, as compared with 10 feet at the surface. The Midland dome has a closure of 40 feet or more in the oil sand, as against 20 feet in the surface beds.

The crests of the deep-seated folds lie to the north of the surface crests in both the Jessie Creek anticline and the Midland dome. In the former the highest point in the Bartlesville sand is about 500 feet due north of the corresponding point shown by the surface beds. In the latter the crest of the Bartlesville dome is about 2,000 feet east-northeast of the crest in the surface beds. Neither of these folds shows pronounced similarity between shallow and deep-seated folding, but in each the offset lies along one axis of the dome.

The relation between the axes of plunging anticlines or anticlinal noses seems to be fairly regular. Without exception, in those available for study, the shallow and deep axes are approximately parallel. On one of the offshoots of the Jessie Creek anticline they practically coincide. On a second they are parallel, but the Bartlesville fold is offset about 1,000 feet to the north. This last relation is shown also by the anticlinal nose in sec. 30, T. 26 N., R. 12 E., and more doubtfully by the one in sec. 18, T. 27 N., R. 12 E. The axes of surface and deep plunging anticlines in sec. 22, T. 27 N., R. 12 E., coincide.

Although all the domes and plunging anticlines manifested at the surface appear to be associated with similar features in depth, the reverse does not necessarily hold, as is shown by the South Butler Creek pool. In that pool the Bartlesville sand is flexed into two domes separated by a shallow syncline. The only surface feature that may be interpreted as a possible reflection of this domal structure is a very gentle anticline whose northeastward-plunging axis crosses above the saddle between the two anticlinal folds in the Bartlesville sand. The fact that the axes of the Bartlesville folds parallel that of the surface fold indicates a relationship, in spite of its slight surface manifestation.

The relation between surface and deep-seated synclinal axes is remarkably regular. With the exception of the sharp trough in the Bartlesville sand in sec. 28, T. 26 N., R. 12 E., such deep and shallow axes agree surprisingly in position, although of course the surface folds are much broader and more gentle than the deeper ones. The Bartlesville syncline in sec. 28, T. 26 N., R. 12 E., appears to be reflected in the surface beds about 2,000 feet to the north.

RELATION BETWEEN STRUCTURE AND PRODUCTION.

It would not be justifiable to attempt, from the meager evidence presented by these two fractional townships, to draw general conclusions applicable to the entire Osage Reservation or even to a large fraction of it. However, the relation between structure and production in these townships should be pointed out in order that it may be a basis for future comparisons.

It may be stated without hesitation that anticlinal structure exhibited by surface beds in this area has in most places indicated commercial amounts of oil. There are within the area eight folds that are marked by gentle doming of the surface beds. Of these, seven have been drilled, and on six of them oil in commercial volume has been found. On four of them oil or gas was found underlying the portion of the surface encircled by closed contour lines on the maps. The one anticline that has failed to yield oil or gas in response to drilling has not been adequately tested, and it is believed certain that oil will yet be found there.

Of the oil pools that have been developed on closed anticlines the largest and most productive pools are on the largest and steepest folds. The best pool on an anticlinal fold in this area is on the Panther Creek anticline, in secs. 18, 19, and 30, T. 26 N., R. 12 E., which is the most pronounced anticline in the area. Second in magnitude is the pool on the Jessie Creek anticline, and third is that on the Midland dome.

The relation of productivity to surface expression of structure is irregular. However, it is worthy of note that the largest wells were not found under the crests of the surface folds on any of the anticlines. On the Panther Creek anticline they are both east and northwest of the crest and about 10 feet below it. On the Jessie Creek anticline they are on the north flank, 10 to 30 feet below the crest. On the North Jessie Creek dome they are low on the north flank. On the Midland dome they are 20 to 30 feet below the crest, on the northeast flank. Without exception the large wells are found north of the surface crest. This is in large part explained by the relation of the surface structure to that of the oil-bearing beds. (See pp. 406–407.)

No general relation between steepness of dip and productivity could be established in this area. Of the anticlines in these townships those with steep flanks have yielded more oil and better wells than the more gentle folds, but it is known that in many other parts of Osage County no such relation exists.

The importance of plunging anticlines can not be judged by the evidence in these townships. It is believed that such anticlines are developed along definite lines of deformation, and that where two such lines intersect, as in the SE. ¼ sec. 18, T. 27 N., R. 12 E. there will be doming of the oil sand with consequent accumulation of oil. Except where such doming is present the plunging anticlines are believed to be only a little more promising territory than the unflexed monoclines, although the excellent yield of the northeastern part of the Wiser Hill pool, in sec. 22, T. 27 N., R. 12 E., may be considered by some to refute this statement.

The single broad terrace or structural flat in this area yields no criteria for comparative statements. On it a number of dry holes and about an equal number of producing wells have been drilled.

The potency of faults in bringing about oil pools is believed to be demonstrated by the Wiser Hill pool and the producing area along Viza Creek. Faults are unquestionably present in these pools, and the existence of the pools may be explained by the presence of faults, known or assumed. However, it must be conceded that the demonstration rests largely upon theory and can not be considered proved.

A review of the locations of dry holes with respect to the structure of the outcropping beds is illuminating. Some 81 dry holes were located by the writers. Of these 10 are high on anticlines, 12 are low on anticlinal flanks, 36 are on monoclines or gentle anticlinal noses, and 23 are in synclines. One well on the Midland dome, shown as a dry hole on the map, did not reach the oil sand. The 22 dry holes listed as on anticlines include five on the North Butler Creek terrace, which is not, properly speaking, an anticlinal fold. Most of the other dry holes on anticlines are either surrounded by producing wells or mark the outer limits of pools. The dry holes in the synclines, on the other hand, are for the most part not associated with producing wells. Of the 35 wells known to have been drilled in clearly defined synclines as shown by the surface beds, 12 have produced some oil, as contrasted to 23 that have been barren.

The relations between production and the structure of the oil sand are more complex than those of production and surface structure. The fact that every important field in the area, with the exception of the Wiser Hill pool, shows doming of the oil sand unquestionably signifies that such doming is important, if not essential. It is true that sharp synclinal folding is also present in the oil sand in some of these fields, but the oil wells are almost without exception in the heads of such synclines, where they rise steeply on the flanks of anticlinal folds. In the Wiser Hill pool, where there is no doming of the oil sand, the accumulation is almost certainly due to faulting. (See p. 415.)

The relation of dry holes to anticlinal structure in the oil sands can not be stated, for the structure of the oil sands is known only in comparatively small portions of these townships. However, it is noteworthy that of all the dry holes in this area but three are known to be on pronounced anticlinal folds in the oil sand.

The outlines of the oil fields are more closely connected with the anticlinal folding of the oil sands than with that of the surface rocks. In all the anticlinal pools the crests and much of the axes of the subsurface anticlines are within the oil-yielding area. The positions of big wells with respect to axes and crests, however, vary greatly.

Only in the South Butler Creek field are the large wells over the crests of the domes. Elsewhere they are from 10 to 60 feet below the crests and are commonly on the west or northwest flanks of the fold; although some have been found on both south and east flanks.

A tendency for oil to be found along certain lines or trends has frequently been suggested. In this area such a tendency is strikingly apparent in the Wiser Hill pool and is also very noticeable southwest of the Viza Creek dome. In both of these localities the trends are to the northeast. There is a suggestion of a northeast trend in the Panther Creek pool. In the South Butler Creek pool the line of producing wells trends due north.

These trends appear to be determined by structural conditions rather than by the distribution and nature of the oil sand or the subjacent shales. The two fields that show the most definite trends are thought to be related to faults that trend in the same directions as the oil pools. Elsewhere the trends conform closely to the axes of deformation in the underlying beds.

STRUCTURE IN DETAIL.

T. 26 N., R. 12 E.

In the parts of T. 26 N., R. 12 E., that are covered by alluvium the structure could not be determined from the surface geology. Such areas include the valley of Turkey Creek in sec. 6, the valley floor of Sand Creek, and portions of secs. 3, 4, and 10. The large synclinal basin, centering in the SW. $\frac{1}{4}$ sec. 4 and the NE. $\frac{1}{4}$ sec. 8 would suggest that the west slope of a fold favorable to oil accumulation occurs in sec. 3. This suggestion is corroborated by the presence of oil wells drilled in the north half of that section and in the section to the east. A structure probably due to faulting occurs in the N. $\frac{1}{2}$ sec. 15.

Panther Creek occupies about the center of a north-south syncline, the largest syncline in the township.

This township has been drilled extensively, and probably the higher sands, including the Bartlesville, have been drained of much of their extractable oil. The drilling, however, has not been deep enough to determine the presence or absence in this township of oil-bearing beds below the top of the "Mississippi lime." The writers have suggested some locations for such exploration in the following detailed descriptions.

Jessie Creek anticline.—The Jessie Creek anticline, so named because it is near the head of Jessie Creek, lies mainly in secs. 33 and 34. It extends northeastward an undetermined distance and southwestward into sec. 4, T. 25 N., R. 12 E., where it is separated from the Forty-seven anticline by a short saddle. The oil obtained in wells on the Forty-seven anticline is said to come exclusively from the Bartlesville sand, the Peru sand being unproductive.[8] In the Jessie Creek anticline, however, many of the wells obtain oil from the Peru sand and many from the Bartlesville sand. The Squirrel sand, though recorded in many of the logs of the deeper wells, is usually noted as barren. One well, however, produced 3,000,000 cubic feet of gas from this sand. Both oil and gas have been produced from this anticline. To the north and the west of its crest the only holes that proved to be dry were far down the sides of the anticline. Of the many wells drilled on this anticline in T. 26 N., R. 12 E., only one, a gas well, appears to have reached the "Mississippi lime." In the northwestern part of the SW. ¼ sec. 32 a dry hole penetrated the Burgess sand, but it is so far down the flank of the anticline as to be almost in the bottom of a syncline and could hardly be expected to produce oil in quantities from any sand. The Jessie Creek anticline is pretty well explored for oil in the Bartlesville and higher sands, but should be drilled to determine the possibility of oil in or below the "Mississippi lime." Good locations for tests of the lower beds are near the center of sec. 33, the center of the west line of the SW. ¼ sec. 33, the center of the SE. ¼ sec. 33, and the center of the south line of the SW. ¼ sec. 28.

During the first quarter of 1921 the portion of this anticline in this township furnished approximately two-fifths of the total production for the township.

North Jessie Creek dome.—The North Jessie Creek dome lies mainly in the SE. ¼ sec. 20 and SW. ¼ sec. 21, with a small part in the extreme northwest corner of sec. 28 and the northeast corner of sec. 29. It has a closure of about 20 feet, but its top is divided into two small slightly domed areas. The southwestern part of this dome has been well tested and is now producing from the Bartlesville sand. It seems possible that the producing area may be extended to the north and to the west. There seems to be a definite trend of productive area southwestward from the Viza Creek dome, which if extended would cross the anticlinal nose extending west from the North Jessie Creek anticline in the SE. ¼ sec. 20. Testing the Bartlesville sand in the center of the SW. ¼ SE. ¼ sec. 20 accordingly seems justifiable. The north half of the top of the dome has not yet been tested, although about half a mile to the northeast some dry holes have been drilled.

Panther Creek anticline.—The Panther Creek anticline is in the western part of secs. 19, 30, and 31 and the adjacent sections of T. 26 N., R. 11 E. As the datum planes used in mapping this township and T. 26 N., R. 11 E., are 465 feet apart, the contours on the map in

[8] Hopkins, O. B., U. S. Geol. Survey Bull. 686–H, pl. 11 and p. 85, 1918.

this paper interfinger with those on the map of the adjacent township.[9] This interfingering slightly changes the shape of the upper closing contours. The fault in sec. 19 is just east of the area mapped by Clark and consequently was not noted by him. The presence of this fault changes somewhat the aspect of the small domes on this anticline, showing that there are but three, instead of four, as he describes.[10]

The oil produced on this anticline is obtained mostly from the Bartlesville sand, although some comes from the Peru sand. The anticline has been fairly well explored so far as these sands are concerned, but the "Mississippi lime" has not been penetrated by many wells nor to any great depth. The deepest well stratigraphically in this township of which the writers have knowledge is in the NW. ¼ sec. 31. This well is said to have been drilled 126 feet into the "Mississippi lime" and to have had an initial production of 26,000,000 feet of gas from the first break in the lime. Most of the oil produced from this anticline is obtained in the township to the west. There is a good possibility, however, that oil may be found below the gas horizon in the upper part of the "Mississippi lime." The 350 or 400 feet of strata below the top of the "Mississippi lime" on this anticline should unquestionably be tested by wells located high on the anticline.

Midland dome.—The Midland dome, named from the Midland Oil Co., which owns the lease on it, occupies the western two-thirds of sec. 5 and probably much of sec. 6. There is also a small subsidiary dome in the SE. ¼ sec. 5. The main dome has a closure of about 30 feet. The fault to the east, if persistent in depth, would add somewhat to the area from which oil might be recovered. The rocks are concealed in the greater part of sec. 6 by alluvium and wash, so that the surface structure there can not be determined. The beds appear to lie very flat, dipping slightly to the west with steeper dips along the south and west edges of the section. It is possible that either a small dome or a small depression may occupy the central part of sec. 6. Four dry holes have been drilled in this section, two on the east edge of the NE. ¼ and one each in the northwest corner and the southwest corner of the NW. ¼. The two latter wells were drilled to the "Mississippi lime," but the writers have no data on the two eastern holes. Just to the east of these holes, in the western part of sec. 5, wells are producing oil from the Bartlesville sand and gas from the top of the "Mississippi lime." Several interpretations of the underground conditions are suggested by the presence of the two dry holes in the eastern part of sec. 6. They may have encountered "tight" sands; they may be just west of the area where the oil has

[9] Clark, F. R., U. S. Geol. Survey Bull. 686–I, pl. 15, 1918.
[10] Idem, p. 116.

collected; or there may be a small dome in the center of sec. 6, which would mean that these two holes were in a small syncline.

On this dome, as on other favorable oil areas in this township, no well has tested the horizons below the upper part of the "Mississippi lime." It is a particularly advantageous location for such a test, as the development has permitted determination of the position of the folding in the Bartlesville sand. The best place for a deep test would appear to be the center of the NW.¼ NE.¼ sec. 5, T. 26 N., R. 12 E.

It is possible that a small pool can be developed on a little dome just east of the fault line in the SW.¼ sec. 5. There is a distinct axis of folding here, and even though the area of the fold is very small, there is a possibility of fair production. The presence of faults suggests the possibility of production from some shallow sand as well as from the Bartlesville sand or the "Mississippi lime."

Sec. 18.—A half dome occupies the SE. ¼ sec. 18. It is made up of beds showing a steep reverse dip on the east and is bounded by a fault plane on the west. There is a probable closure of at least 70 feet against the fault. As the greater part of sec. 18 is covered with alluvium, it is not possible to determine the exact structural conditions. Unless an unmapped fault occurs in the alluvium-covered area of Sand Creek, the structure is probably about as indicated on the map (Pl. LVII). This half dome has a very small area from which to drain oil and may for that reason yield but little. However, the fault plane may have acted as a conductor of oil from deeper beds, and the dome should certainly be tested. A good location for such a test is a little north of the center of the SW.¼ SE.¼ sec. 18.

A depression occurs in this section, and its deepest part is just a little east of the center of the section. A number of wells have been drilled in the SW.¼ sec. 18, but the writers have been unable to procure logs of these wells. From the surface structure it would appear to be undesirable to drill more wells in this section, except as suggested above.

Viza Creek dome.—The Viza Creek dome occupies the NW.¼ sec. 15 and part of the NE.¼ sec. 16. Its presence is suggested by the outcrop of the Dewey limestone. The cover of alluvium conceals most of the surface detail of this dome. The underground structure shows strong dips to the east and south, but lack of positive evidence leaves the condition of the northwest side of the dome a matter of surmise. However, the suggestive evidence (see p. 409) indicates that a major portion of the dome closes against a concealed fault to the northwest. Unlike the somewhat similar dome in sec. 18, this dome is probably free to drain oil from the south and southwest. Oil is obtained in it from both the Peru and the Bartlesville sands.

T. 27 N., R. 12 E.

A small portion of T. 27 N., R. 12 E., is covered with alluvium, so that no surface structure contours could be drawn for sec. 34 and parts of secs. 27, 28, and 33. The most prominent structural features are a flat with slight doming that occupies the central part of the township, a pronounced syncline that plunges westward across the township about 1½ miles south of the north edge, four faults, and five plunging anticlines, two of them with local doming. To the lack of pronounced doming is probably due in part the small amount of drilling that has been done in the north half of the township. The presence of these faults and the long axes of the plunging anticlines, considered in connection with their probable relation to oil production and subsurface conditions, make the study of this township of special interest to the oil man as well as to the geologist.

Wiser Hill pool.—The Wiser Hill pool occupies the NE. ¼ and S. ½ sec. 21, the north third of sec. 28, and most of secs. 15 and 22. This area is locally known as Wiser Hill, from the oil company that is operating the leases. Over 90 wells have been drilled in this pool. The oil is obtained from a sand 12 to 22 feet thick, known locally as the "shallow sand." This sand is recorded as being from 30 to more than 100 feet above the Big lime and from 117 to 222 feet or more above the Peru sand, but some of this variation is probably due to inaccuracy in the logs, for the logs showing the lower sands are old and appear to be generalized. The wells drilled in this pool to the Peru and Bartlesville sands found them nonproductive of oil. Wells east of the pool, in the Washington County part of this township, obtain oil from the Bartlesville sand but none from the "shallow sand." This sand, or at least a thin sand that bears the same relation to the Big lime, is recorded in some of the logs from other parts of the two townships considered in this paper, but no oil appears to have been noted in it, although some of the wells whose logs record its presence are favorably located with reference to the structure. Showings of gas recorded in secs. 29 and 32 of this township appear to come from this sand.

At least three sands that lie stratigraphically above the "shallow sand" of the Wiser hill pool have given showings of gas in wells drilled in Tps. 26 and 27 N., R. 12 E., and apparently they have in some logs been confused with the sand of the Wiser Hill pool. These sands are about 675, 560, and 450 feet above the Big lime, and the lowermost of them is therefore 300 feet or more above the horizon of the "shallow sand" of the Wiser Hill pool. The highest of these sands contains some gas in sec. 34, T. 26 N., R. 12 E. The next lower one yielding gas shows in sec. 29, T. 27 N., R. 12 E., and in secs. 5 and 34, T. 26 N., R. 12 E. The lowermost sand showed a gas content in sec. 17, T. 27 N., R. 12 E., and secs. 5 and 34, T. 26 N., R. 12 E.

The surface geology shows that a fault in secs. 16, 21, and 22 cuts through the middle of this pool. The subsurface geology indicates that this fault has a greater throw at the horizon of the "shallow sand" than at the surface. The portion of the pool on the west side of the fault is on a gentle raise from a structural flat or terrace to the northwest. The portion of the pool on the east side of the fault is on beds having a much steeper northwest dip. A second fault occurs just southwest of this pool. West of this fault oil is produced from the Bartlesville sand but none from the "shallow sand." It is also noteworthy that the long fault in sec. 33 and in T. 26 N., R. 12 E., is parallel in trend to the Wiser Hill pool. Whether or not this particular fault affects the "shallow sand" southeast of the pool, the fact that the Wiser Hill pool has practically the same alinement must be considered significant.

The oil in this pool may have been derived from the shales just below the "shallow sand," or it may have escaped from lower sands along a fault plane or planes and collected in the "shallow sand." If the subjacent shale was capable of yielding enough oil to justify the drilling of more than 90 wells, at least two of which were put down as early as 1904, it is only reasonable to expect that similar oil-producing conditions at this horizon would manifest themselves elsewhere in these townships. If such conditions exist, however, they have not been discovered. On the other hand, if the occurrence of a large amount of oil in the "shallow sand" in this pool is due to the collection of oil that has escaped from a deeper sand along a fault line, the barrenness of lower beds in this pool and of the "shallow sand" outside of this pool is explained.

No anticlinal structure is present in this pool, either in the surface beds or in the oil sand, and although the southern part of the field is on the edge of a terrace in the surface beds, no such structure is certainly present in the producing sand. This condition argues against a normal type of oil accumulation.

It seems probable that the pool contains oil that migrated up the dip of deep oil-bearing sands and found an avenue of escape to the "shallow sand" along the faults in secs. 20, 28, and 29 and in secs. 16, 21, and 22. The retention of the oil was probably effected either by sand conditions or by a third fault, not manifest at the surface, which trends northeastward along the southeast boundary of the field. The outline and extent of the pool may also have been influenced by the northward-plunging anticlinal nose in sec. 22. If this hypothesis is correct oil is not necessarily to be expected in the deep beds below this pool, as there is no reason to believe anticlinal structure favorable to its accumulation exists there.

South Butler Creek pool.—The South Butler Creek pool occupies the southeast third of sec. 29, the E. ½ and part of the SW. ¼ sec. 32, and a small area in the SW. ¼ sec. 28. From the surface structure this pool appears to be merely the steeply dipping north slope of the Midland dome, which lies in the northern part of the township to the south. The only doming shown by the surface beds is on a nose in the western part of sec. 32 and the NW. ¼ sec. 31, which has a single closed contour on its north end. This closure is west of the pool, and the area has not yet been tested. The east edge of the pool is limited by two faults, to which is probably due in part the marked difference in the structure of the surface beds and the Bartlesville sand. Plate LVIII (p. 408) shows that in the E. ½ sec. 32 and the SE. ¼ sec. 29 the surface beds have a slightly varying northward dip.

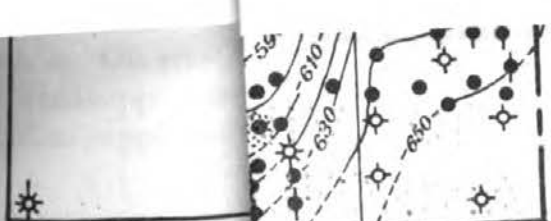
Plate LIX (p. 412) shows that the "Oswego lime" is arched into a low dome whose crest is near the center of the NE. ¼ sec. 32. South of this dome there is an anticlinal nose that plunges northwestward across the SE. ¼ sec. 32.

The folding in the Bartlesville sand in this area agrees in a general way with that in the "Oswego," but it is more complex. Instead of a single dome, two are shown, one in the SE. ¼ sec. 29 and the other in the NE. ¼ sec. 32. There is also a plunging anticline in the SE. ¼ sec. 32 which is more pronounced than the similar fold in the "Oswego."

This pool has not been outlined by dry holes, and it seems probable that it will extend from the south-central part of sec. 29 into the NW. ¼ sec. 32. Certainly the surface structure and the observed relations between the surface and deep folding justify a test there. A good location for such a test would be the center of the NW. ¼ NW. ¼ sec. 32. A good location for testing the beds in and below the "Mississippi lime" would be the center of the SE. ¼ SE. ¼ sec. 29.

Backius anticline.—Most of the Backius anticline lies in T. 27 N., R. 11 E., but a curved spur extends eastward into the west-central part of sec. 31, T. 27 N., R. 12 E., dying out in a structural saddle about 1,000 feet northwest of the south quarter corner of the section. This anticline has yielded both oil and gas in notable amounts. The portion in T. 27 N., R. 12 E., was drilled many years ago, and a small gas field was developed on it. So far as known the wells yielded no oil.

North Butler Creek terrace.—The North Butler Creek terrace occupies the eastern two-thirds of sec. 17, the W. ½ sec. 16, and the adjacent parts of secs. 20 and 21. In sec. 17 there is a single closed contour. In the center of the area outlined by this contour a dry hole was drilled 273 feet into the "Mississippi lime." From the



MAP SHO RTLESVILLE

log of this well it appears that the Peru and Squirrel sands are absent and that the Bartlesville sand is thin. This log is shown as No. 2 on Plate LVI. Oil, however, is produced from the Bartlesville sand and from a sand at the top of the "Mississippi lime" on the edges of this terrace.

The portion of this terrace that is structurally most favorable is the SW. ¼ sec. 18, where an axis of folding extending westward from the central low flat of the North Butler Creek terrace is intersected by a northward-trending axis that is parallel to and about 1,000 feet west of the east line of secs. 30 and 19. There seems to be anticlinal folding in the "Oswego lime" where these two axes intersect. A number of wells have been drilled in the SE. ¼ sec. 18 and the NE. ¼ sec. 19, but the producing territory can probably be extended to the north and east.

It is probable that there is a similar intersection of less pronounced axes on the northeast flank of the terrace in the northeast corner of sec. 17 and the southeast corner of sec. 8. This inference is strengthened by the contour of the tops of the "Oswego lime" and Bartlesville sand as revealed by the records of two oil wells and two dry holes that have been drilled on this part of the terrace. There seems to be decided doming in these lower beds, and it will be noted that this doming is to the northeast of the surface doming, its relative position agreeing in this respect with that of the subsurface folds in other parts of these townships. It seems probable that prospecting north and east of the corner of secs. 7, 8, 17, and 18 will be repaid by production.

Secs. 4 and 5.—A structural nose or plunging anticline trends westward across the northern parts of secs. 4, 5, and 6. This nose is modified by gentle doming on the line between secs. 4 and 5, due, apparently, to the north-south axis of folding that affected the northeastern part of the North Butler Creek terrace.

No wells have been drilled in this area, and as the surface structure indicates that there should be pronounced doming in depth, and as this nose should receive the oil from much of secs. 5 and 6, it is recommended that a test be drilled near the east line of the S. ½ NE. ¼ sec. 5. Oil may be found in the Bartlesville sand, at the top of the "Mississippi lime," or about 350 to 400 feet below the top of the "Mississippi lime."

OIL AND GAS.

Development.—Oil was discovered at Bartlesville, just east of the area mapped, in 1894, but owing to complications in leases, active operations were not begun until about 10 years later. There were no wells of great yield, although some are said to have had an initial daily production of 1,000 barrels, but there were many that started with several hundred barrels a day, and the Bartlesville-Dewey pool soon attracted widespread attention. The pool was rapidly developed, and in 1906 the production began to decline. In that year the average initial daily production was about 73 barrels, and by 1914 this average decreased to 10.4 barrels. It is reported that at the end of 1914 there were 4,816 producing wells in the pool.[11]

The western part of the Bartlesville-Dewey pool extends into the area here mapped, but because of its location in Osage County, where conditions of leasing are different, development has been retarded.

Active drilling was begun in 1903 in the eastern tier of sections of T. 26 N., R. 12 E., in Osage County, adjacent to the developed area in the vicinity of Bartlesville. A number of good wells were found, including a few small gushers. Drilling soon spread throughout the leased area, and by 1917 at least 464 wells had been sunk in the area here considered. Of these, 139 were in T. 27 N., R. 12 E., and 325 in T. 26 N., R. 12 E. About 20 per cent of those in the northern township and 14 per cent of those in the southern township were dry holes. By the middle of 1921 at least 703 wells had been drilled in this area, about 232 in the northern township and 471 in the southern township, of which about 20 per cent and 18 per cent respectively are dry. Many wells have, of course, been abandoned.

Production.—For the three months of January, February, and March, 1921, the total production of oil in the Osage County portion of T. 27 N., R. 12 E., was 20,132.4 barrels from 134 wells, or an average of about 50 barrels per well per month. During the same period the southern township did slightly better, producing 49,712.9 barrels from 267 wells, or an average of about 62 barrels per well per month. The production from six sections, three in each township, containing a total of 48 producing oil wells, was 2,111.6 barrels for this three-month period, or an average of about 14⅔ barrels per well per month, or half a barrel per day. These six sections were selected as representing the smallest production, but the producing wells are situated near more prolific wells in adjacent sections. During the corresponding three months of 1917 the average production for the same six sections was about 27 barrels per well per month.

Many of the older wells declined so that they produced but little oil, yet during the period of high prices for crude oil they could be pumped with profit when the pumper could attend to them in addition to more productive wells.

The logs of many of the wells in these two townships are very incomplete, some of them giving only the depth from which oil was produced. Many of the present lessees do not even possess records of all the wells drilled on the area now under their control. Of the

[11] Oklahoma Geol. Survey Bull. 19, pt. 2, p. 510, 1917.

available logs many fail to mention initial production. Some indicate only the production in the first 24 hours after the well was shot and some only that in the first 24 hours natural yield. Therefore the term "initial production" as used here may indicate either period, but where the production for both periods is given in the logs, the larger production has been used. In the following discussion and averages dry holes are not considered.

In the Osage portion of T. 27 N., R. 12 E., records of the initial production of 94 wells have been procured. Of these, 22 wells showed 50 barrels or more, including 7 that came in with 100 barrels or more. The average initial production was 35¼ barrels. In T. 26 N., R. 12 E., of 130 wells whose initial production is on record, 38 made 50 barrels or more, including 10 that produced 100 barrels or more. The average was 38½ barrels.

Wells having an initial production of 50 barrels or more occur in 15 sections in this area, and most of these are located where the structure as determined from surface outcrops is favorable. Faults and anticlinal folds appear to be the main factors in determining the favorable localities. One area, the eastern part of sec. 9, T. 26 N., R. 12 E., where the initial production was large and the surface structure not exceptionally favorable, is adjacent to an alluvium-covered area on the east, under which a concealed fault probably exists, causing the larger production in that area. Structural evidence of a concealed fault was found in the section to the south, and this occurrence may be suggestive evidence of the northeastward extension of that fault.

Quality.—The quality of the oil and gas obtained in this area is shown by the following analyses:

Analyses of crude petroleum from Tps. 26 and 27 N., R. 12 E.

[By Ernest W. Dean, Bureau of Mines. Air distillation with fractionating column; barometer 735 millimeters for Nos. 00107 and 00106; 747 millimeters for No. 00108.]

Laboratory No.	Source and character of sample.	Temperature (°C.).	Fractions (per cent by volume).	Total distilled (per cent by volume).	Specific gravity.
00107	Peru sand, well No. 23, Skelton-Moore Oil Co., SW. ¼ sec. 34, T. 26 N., R. 12 E. Specific gravity at 15° C., 0.854 (33.9° Baumé). Sulphur, 0.13 per cent.	Up to 75	5.0	5.0	0.684
		75–100	5.2	10.2	.724
		100–125	4.3	14.5	.752
		125–150	5.2	19.7	.768
		150–175	5.1	24.8	.788
		175–200	3.8	28.6	.804
		200–225	4.5	33.1	.816
		225–250	5.5	38.6	.832
		250–275	5.5	44.1	.846
00106	Composite sample from "shallow sand" from several wells of Wiser Oil Co., sec. 21, T. 27 N., R. 12 E. Specific gravity at 15° C., 0.856 (33.6° Baumé). Sulphur, 0.15 per cent.	Up to 75	2.5	2.5	....
		75–100	4.5	7.0	.720
		100–125	6.1	13.1	.745
		125–150	4.5	17.6	.762
		150–175	4.9	22.5	.78[illegible]
		175–200	4.6	27.1	.7[illegible]
		200–225	4.6	32.7	.[illegible]
		225–250	5.3	38.0	.[illegible]
		250–275	5.7	43.7	.[illegible]

Analyses of crude petroleum from Tps. 26 and 27 N., R. 12 E.—Continued.

Laboratory No.	Source and character of sample.	Temperature (°C.).	Fractions (per cent by volume).	Total distilled (per cent by volume).	Specific gravity.
00106	Bartlesville sand, well No. 24, Indian Territory Illuminating Oil Co., SE. ¼ sec. 32, T. 27 N., R. 12 E. Specific gravity at 15° C., 0.866 (31.7° Baumé). Sulphur, 0.15 per cent.	Up to 75	4.3	4.3	.713
		75–100	4.5	8.8	.762
		100–125	2.0	10.8	.792
		125–150	3.5	14.3	
		150–175	3.0	17.3	.806
		175–200	5.4	22.7	.81[illegible]
		200–225	4.5	27.2	.826
		225–250	6.4	33.6	.832
		250–275	7.0	40.6	.842

These results show that the samples tested represent high-grade petroleum, the specific gravity of which at 15° C. ranges from 0.854 to 0.866 (33.9° to 31.7° Baumé) and which yields on distillation up to a temperature of 200° C. between 22.7 and 28.6 per cent by volume.

Analyses of natural gas from Tps. 26 and 27 N., R. 12 E.

[By S. H. Katz, Bureau of Mines.]

Laboratory No.	Source of samples.	Methane (CH_4).	Ethane (C_2H_6).	Carbon dioxide (CO_2).	Nitrogen (N_2).	Oxygen (O_2).	Specific gravity (air=1).	British thermal units per cubic foot at 760 millimeters.
9294	Top of "Mississippi lime," gas well No. 45, Indian Territory Illuminating Oil Co., NW. ¼ sec. 31, T. 27 N., R. 12 E.	93.2	0.8	4.0	2.0	0.0	0.60	1,008
9316	Composite sample from Bartlesville sand, wells Nos. 9, 12, 15, and 28, Skelton-Moore Oil Co., sec. 34, T. 26 N., R. 12 E.	40.7	57.7	.3	1.1	.2	....	....
9315	Peru sand, well No. 23, Skelton-Moore Oil Co., SW. ¼ sec. 34, T. 26 N., R. 12 E.	11.9	85.7	.5	1.6	.3	....	....

The above analyses show the composition of three samples of natural gas from the sources indicated, collected in November and December, 1917, by air displacement. The high methane content of sample No. 9294, 93.2 per cent, is typical of a dry gas although the 4 per cent of carbon dioxide is somewhat unusual. The other samples show different proportions of methane and ethane in wet gases. The small amounts of oxygen probably represent air leakage.

INDEX.

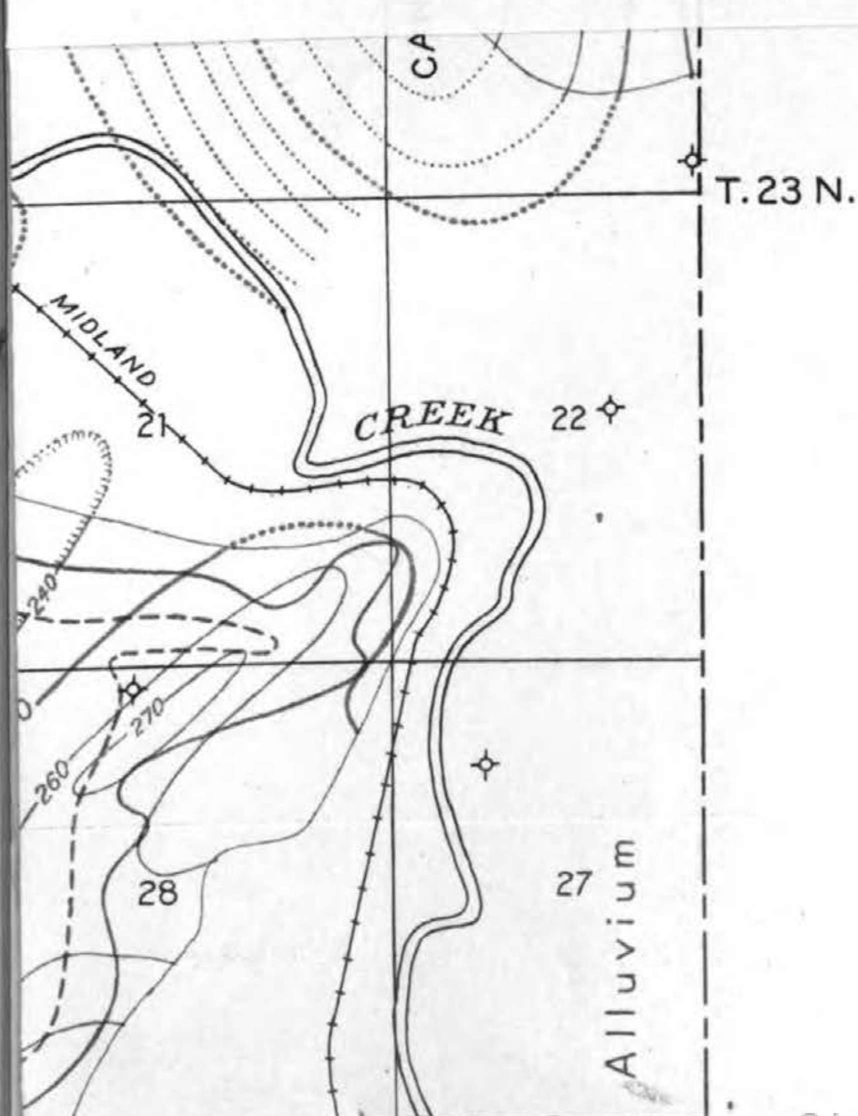
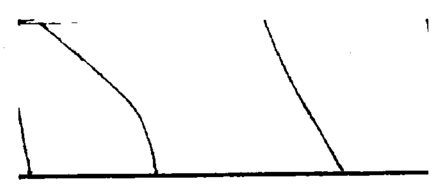

CA
T. 23 N.
MIDLAND
21
CREEK
22
240
270
260
28
27
Alluvium

PLATE IV

. 27 N., R. 9 E.

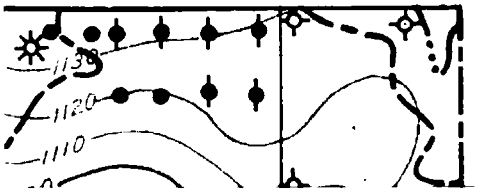


., K. ÿ E.

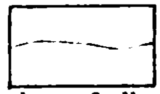
Mile

20 N.,

1 MI



EXPLANATION



Boundary of alluvium

Mile

file

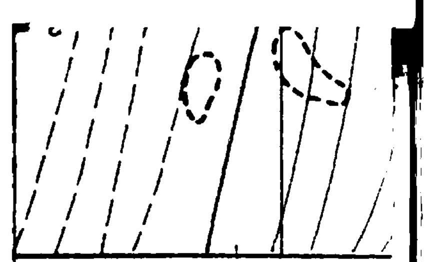
'LATE XIV

5 N., R. 10 E.

le

PLATE XVIII

T. 20 N., R. 11 E.

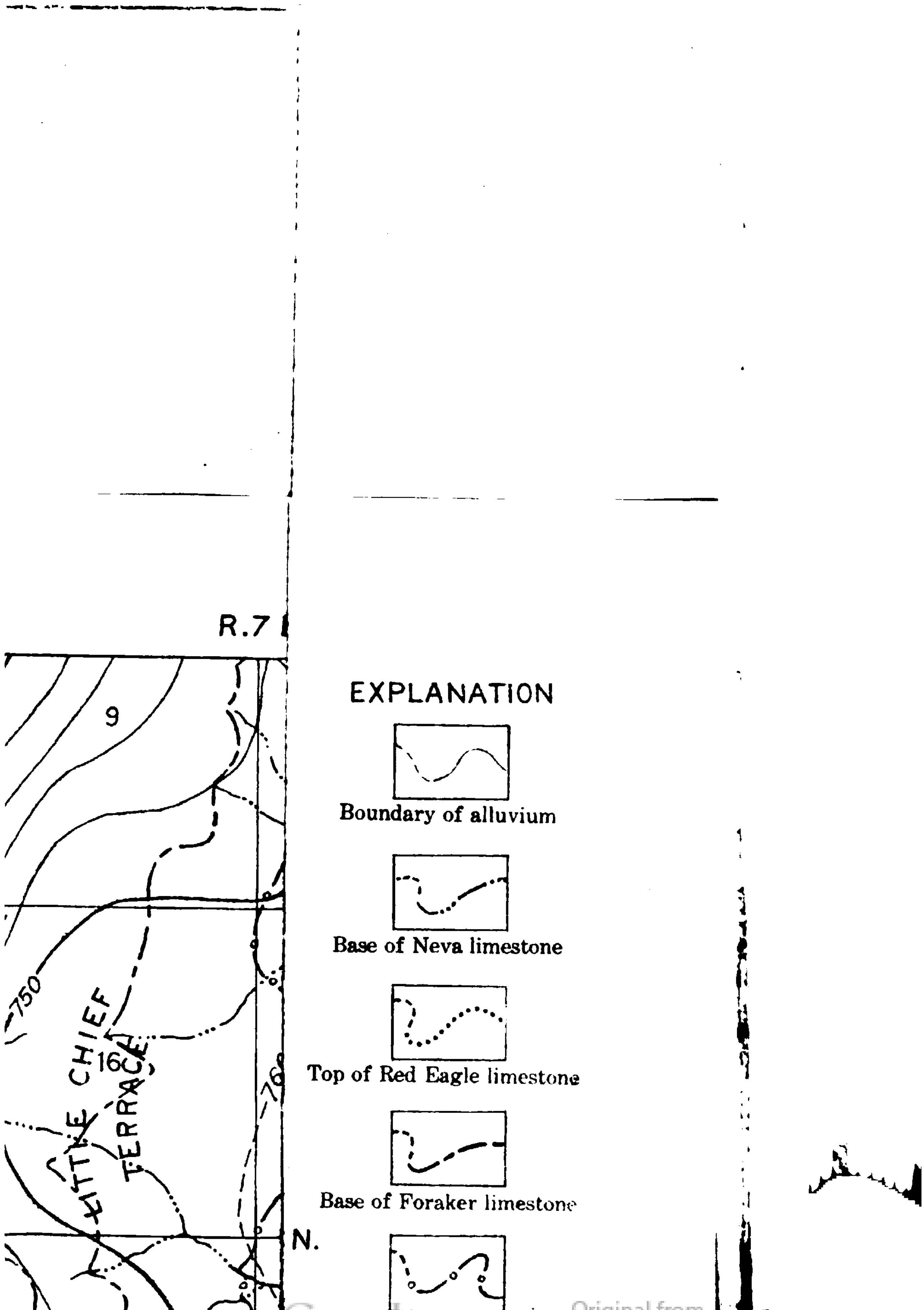


T. 26 N., R. 7 E., OKLAHO

ile

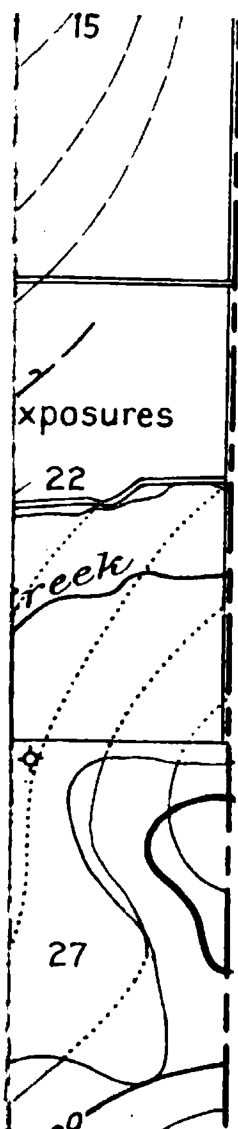
PLATE XX

27 N., R. 7 E.


R.7
9
750
LITTLE CHIEF
TERRACE
16
76
N.
EXPLANATION
Boundary of alluvium
Base of Neva limestone
Top of Red Eagle limestone
Base of Foraker limestone

R. 8 E., OKLAHOMA

1 Mile



Gas well

Abandoned oil well

Abandoned gas well

Oil well with show of gas

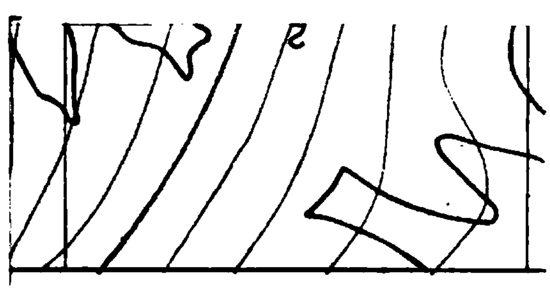
Dry hole

Dry hole with show of oil

Well data compiled from oil company maps and records of Osage Agency
Locations approximate

.ATE XXIX

1 N., R. 11 E.

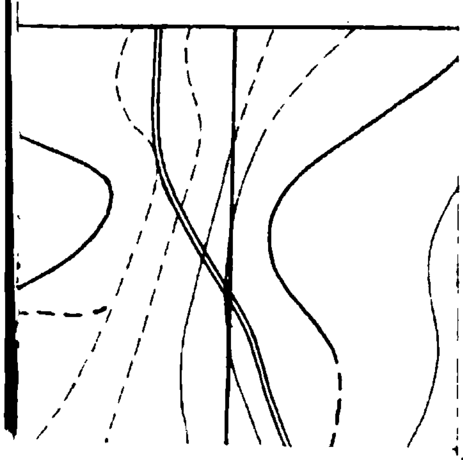


OKLAHOMA

iles

PLATE XXXII

24 N., R. 9 E.



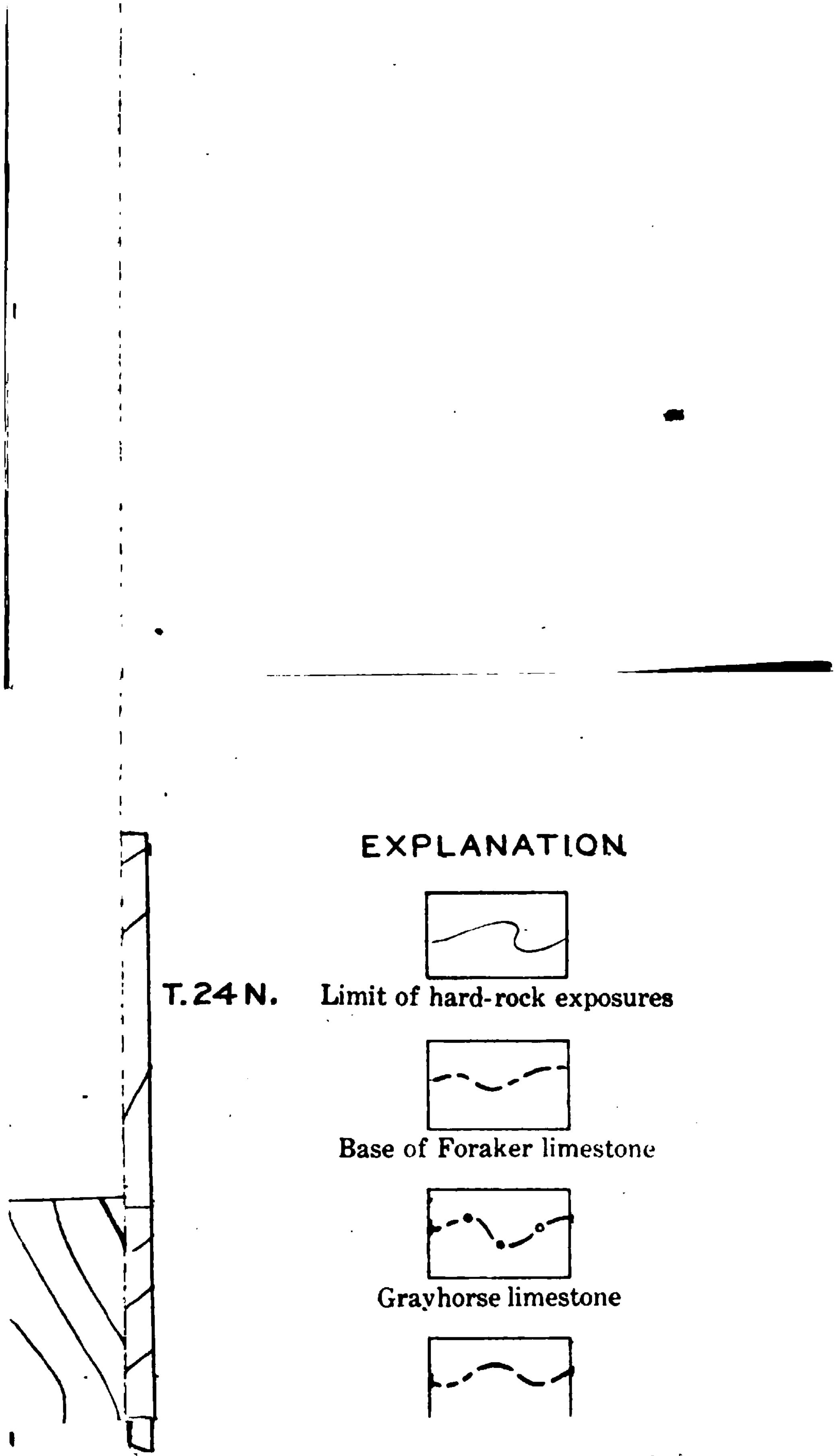

1 Mile

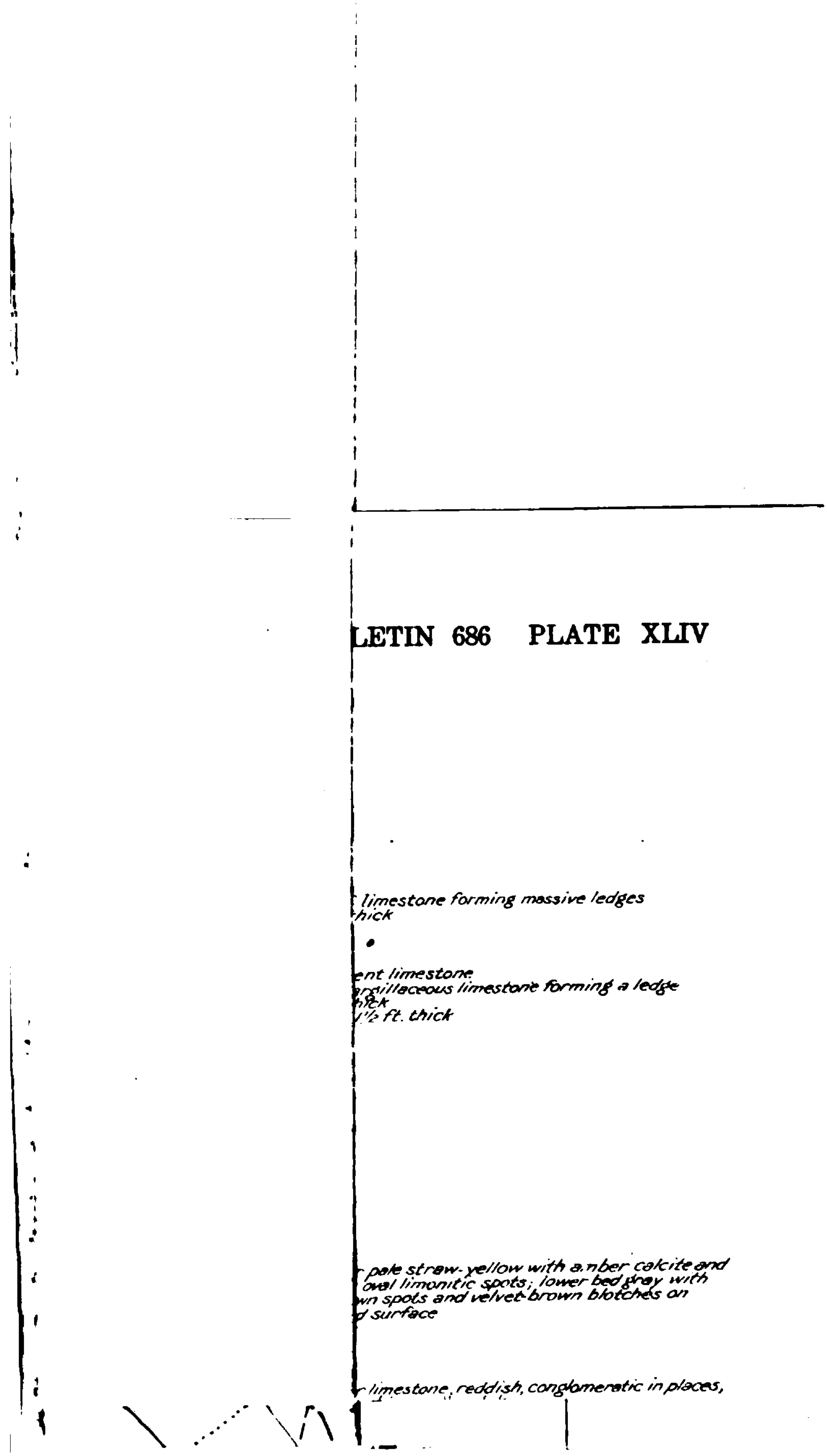
PLATE XXXVII

PLATE XXXVII

E., OKLAHOMA

Mile


EXPLANATION
T. 24 N.
Limit of hard-rock exposures
Base of Foraker limestone
Grayhorse limestone


limestone forming massive ledges
hick
ent limestone
rgillaceous limestone forming a ledge
hick
1½ ft. thick
pale straw-yellow with amber calcite and
oval limonitic spots; lower bed gray with
wn spots and velvet-brown blotches on
d surface
limestone, reddish, conglomeratic in places,

E., OKLAHOMA

Mile

E., OKLAHOMA

lile

PLATE XLI

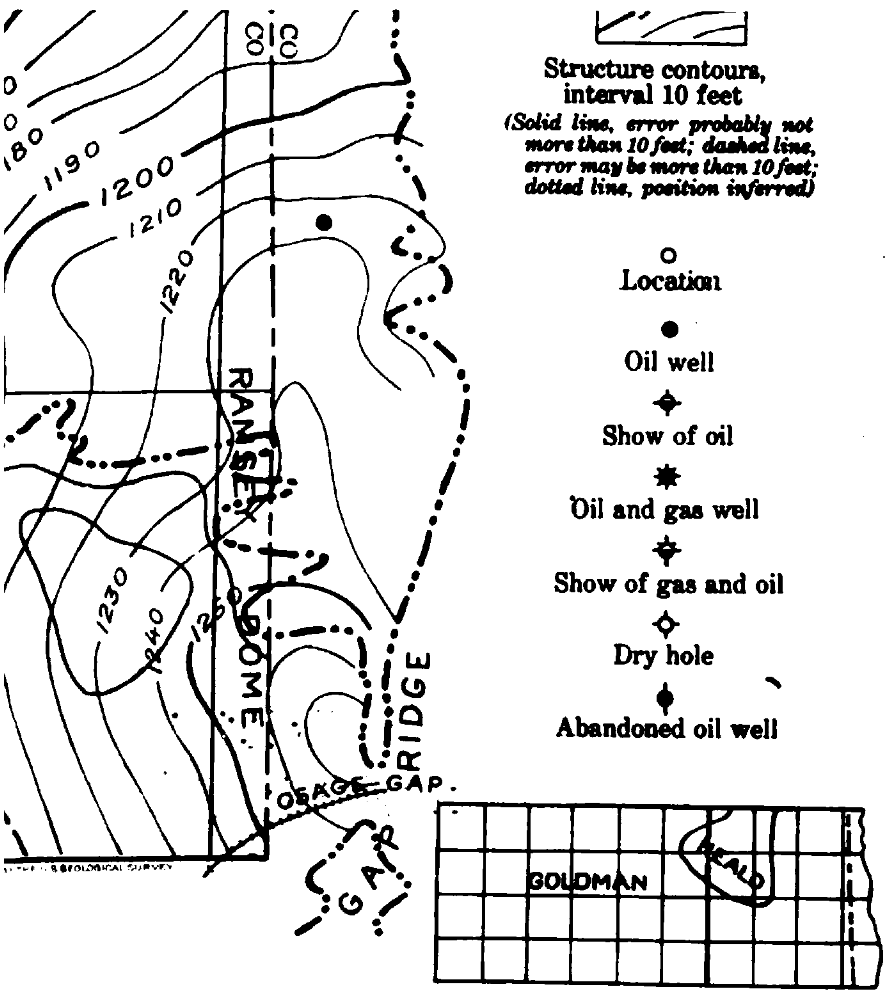
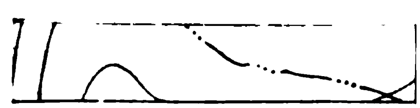

Structure contours, interval 10 feet
(Solid line, error probably not more than 10 feet; dashed line, error may be more than 10 feet; dotted line, position inferred)
Location
Oil well
Show of oil
Oil and gas well
Show of gas and oil
Dry hole
Abandoned oil well
1180
1190
1200
1210
1220
1230
1240
1250
RAMSEY DOME
RIDGE
OSAGE GAP
GAP
GOLDMAN
HEALD

PLATE L

T. 20 N., R. 10 E.



EXPLANATION